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Experiments on the Control of European Bindweed (*Convolvulus arvensis* L.)

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BOTANY AND PLANT PATHOLOGY SECTION

AMES, IOWA

CONTENTS

SUMMARY

European bindweed (*Convolvulus arvensis* L.) is the most serious weed menace in Iowa. During the last 15 years it has become well established in the western half of the state, especially in the northwestern part.

The European bindweed comes through the ground the latter part of April and attains its most profuse growth during the latter part of June and first part of July.

The root system of the European bindweed may penetrate to a depth of 20 feet. A large number of secondary roots are developed in the upper 18 inches. The rhizomes help to extend the areas occupied by the weed.

The seeds of the European bindweed live in the soil for several years. Many of the unripened seeds may germinate. Mature seeds when treated with 75 percent sulfuric acid or seeds with their seed coats scarified germinate readily. Where infested areas have been treated with sulfuric acid or powdered sulfur, there is usually a large number of bindweed seedlings.

European bindweeds flower profusely the latter part of June and the first part of July. Seed setting takes place when the temperature is high and the humidity low.

The European bindweed depletes the soil of moisture and reduces the crop yield. In 1930, measurements of vegetative growth showed that the grain yield was suppressed where the corn had to compete with bindweed.

Sodium chlorate has proved to be the most effective herbicide studied. The usual concentration is 1 pound per gallon. The addition of 4 grams of powdered animal glue and 3 cc. concentrated sulfuric acid improved the herbicidal action of the chlorate. Atlacide made previous to 1932 generally did not give such good results as did sodium chlorate.

Climatic conditions have much to do with the effectiveness of sodium chlorate as a spray. Results obtained in 1933, when the temperature was high and the humidity low, were rather poor. When there has been sufficient humidity to produce dew at night, the results from spraying have been good. Three applications of either sodium chlorate or Atlacide sprays have given complete eradication of European bindweed in one season. Good results have been obtained from spraying in June, August, September and October. Plants appearing the second year have proven to be difficult to handle. No matter how few plants

come up the second year, they should be given two sprays during the season or otherwise exterminated.

Results indicate that spraying with sodium chlorate should be done when there is a heavy development of leaf surface.

Heavy infestations of European bindweed are as easily killed by sodium chlorate as are light infestations.

Best results from sodium chlorate have been obtained when the spraying has been done with the European bindweed growing in small grain or with a smother crop such as millet. Plowing and seeding an infested area to winter rye, spraying the first time in early July of the following summer and the second time the first part of September, have given consistent results. Under favorable conditions, two sprays may eradicate the bindweed in one season.

Sodium chlorate in solution has given more consistent results than the dry salt applied on the soil. More effective killing has resulted with the dry salt when it was placed in the soil.

Potassium chlorate was about as effective as sodium chlorate. Ammonium thiocyanate in quantities of 8 to 12 pounds per square rod applied in 1 year upon the European bindweed gives some promise as a herbicide where areas are small.

Sulfuric acid has not proven to be effective against the bindweed. It may have some value in killing the top growth, and the new growth later may be handled more easily through chlorate herbicides.

C. K. (creosote-kerosene) 10-90 spray will kill the aerial parts of the European bindweed but has little effect on the underground parts.

Ordinary salt (sodium chloride) is not recommended for the eradication of the European bindweed. Where the necessary amounts of sodium chloride are used, the ground becomes sterile and remains so for several years.

Iron sulfate, borax, hypochloride of lime, zinc sulfate and kainite, a commercial fertilizer, have proven to be of little value in the eradication of the European bindweed.

Fallowing for 2 years with a spring toothed harrow from June 1 to Oct. 1 did not eliminate all the European bindweed.

Surface cultivation of corn infested with bindweed has been ineffective in producing any material reduction in the European bindweed population.

Winter rye followed by alfalfa seeded in August has proven an effective way of suppressing the European bindweed.

Soybeans, millet, cane and sudan grass are valuable smother crops and can be used to advantage in reducing the amount of bindweed.

An infested field in small grain should be plowed immediately after harvest and seeded to a smother crop if there is sufficient moisture. If sufficient moisture is not present in the upper surface, the ground should be fallowed the remainder of the year. Shallow cultivations made twice a week are better than cultivations made once a week.

Application of one sodium chlorate spray late in the fall followed by fallowing in the spring to the middle of June and then seeding with a smother crop materially reduced the European bindweed population.

Two years of spring fallowing followed by drilled soybeans at the rate of 2 bushels per acre for 2 years has reduced the number of bindweed.

Alfalfa is the most valuable competitive crop to use in reducing the amount of European bindweed. The seeding of alfalfa should be done the latter part of August.

Alfalfa was shown to be tolerant to residual sodium chlorate in the soil. It is, therefore, the best plant found so far to use where sodium chlorate treatments have been made. Sweet clover, which was as tolerant of sodium chlorate as alfalfa, was not as efficient a smother crop.

Soybeans are particularly sensitive to small amounts of sodium chlorate remaining in the soil and so cannot be used as a "follow-up" crop on ground treated with sodium chlorate.

Oats and barley are sensitive to sodium chlorate, but not so sensitive as soybeans. Corn is not so sensitive to sodium chlorate as the small grains.

Intensive pasturing with sheep and hogs did not reduce materially the European bindweed population.

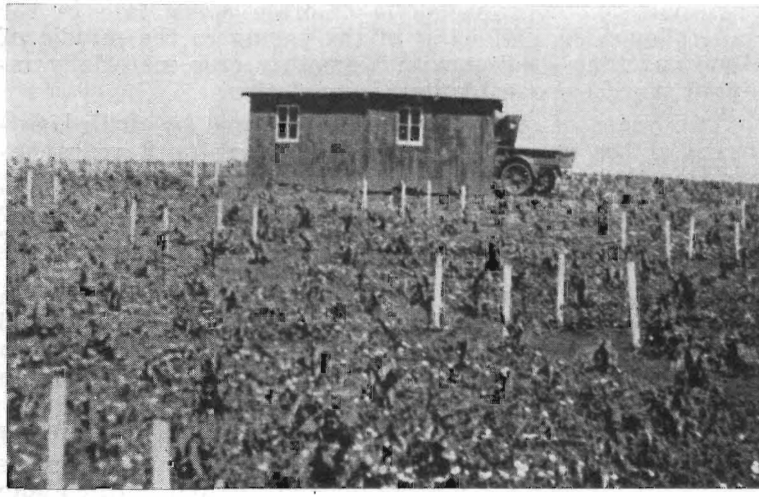

Fig. 1. General view, showing the distribution of European bindweed near the field laboratory building at Hawarden, Iowa, in 1931.

Experiments on the Control of European Bindweed (*Convolvulus arvensis* L.)[1]

By A. L. Bakke

European bindweed (*Convolvulus arvensis* L.) is found in every county in Iowa. It is more prevalent in the western and northwestern parts of the state where 100-acre tracts are common. Many farms have become heavily infested during the last 10 years. European bindweed reduces crop yields, increases the cost of production, threatens land which is free of weeds and finally reduces all land values in its vicinity. It is a serious pest not only in Iowa but also in South Dakota, Minnesota, Nebraska, Kansas, Colorado, Idaho, Washington, Utah and California. It occurs in northeastern North America and sparingly in southeastern United States.

Although considerable work has been done on the control of European bindweed, the methods are still indefinite and conflicting. The purpose of this publication is to show the effectiveness of a number of chemicals and different cultural practices in its control and extermination.

DISTRIBUTION

European bindweed, a native of Europe and Asia, was named *Convolvulus arvensis* by Linnaeus (30). De Candolle, in his Prodromus (19) published in 1845, stated that the species occurred in Europe, Asia, Egypt, Arabia, Mexico and South America. Irmisch (25) in 1857 designated *Convolvulus arvensis* as a vigorous weed ("lästiges Unkraut"). Hegi (23) has reported the species as extending from northern Europe to southeastern Norway. It is missing in the tropics. According to Post and Dinsmore (36), it is common in Syria and Palestine.

European bindweed probably was introduced into this country along the Atlantic coast. Torrey (43) described the species in 1843 in his Flora of the State of New York. Millspaugh (33) stated that *Convolvulus arvensis* became naturalized in the northeastern United States. With the western movement of settlers the plant, no doubt, was introduced into new locations. According to data accompany-

[1] Project 484 of the Iowa Agricultural Experiment Station.

Fig. 2. The European bindweed often covers the entire surface between corn hills.

ing specimens deposited in the herbarium at Iowa State College, *Convolvulus arvensis* was first collected in Iowa in Fayette County in 1893. However, Kiesselbach, Petersen and Burr (29) state that the European bindweed was reported from Iowa in 1889, Kansas in 1877 and Nebraska in 1888. Sheldon (40) collected plants from Dalton, Ottertail County, Minnesota, 1892.

BOTANICAL DESCRIPTION

According to Hegi (23), Gray (21), Britton and Brown (14), Rydberg (38) and Jepson (26), *Convolvulus arvensis* has stems procumbent, or low twining, 2 to 8 cm. long, glabrous; leaves ovate-oblong, arrow or halberd-shaped with lobes at the base acute, more or less spreading, entire; bracts, subulate, minute; peduncles mostly one-flowered; corolla 1.5 to 2.5 cm. long, white with a rose shade, campanulate. Stamens inserted on the tube of the corolla; filaments dilated at the base; calyx not bracted at the base; stigmas linear; ovary entire; fruit, two-celled, globose, capsule; seeds, two in each cell; cotyledons broad, foliaceous. Seeds somewhat pear-shaped, 3 to 4 mm. long, finely dotted, dark brown to black. Perennial with long tap root 20 to 125 cm. long, producing lateral roots. Plants, seldom found individually, are mostly in the open, in com-

pact loam, sandy loam, in fields, road-sides, waste places and gardens.

De Candolle (19) and Hegi (23) have recognized the possibility of several closely related species or varieties.

DEVELOPMENT OF BINDWEED

GERMINATION OF BINDWEED SEED

Numerous germination tests have been made on immature and mature seeds. Many of the immature seeds germinate immediately, while many of the mature ones remain dormant for a considerable time. Treating the mature seeds for 1 hour in a 75 percent sulfuric acid solution or scarifying the mature seeds with a file produced prompt and high percentage germination. In 1937, European bindweed seeds treated with concentrated sulfuric acid for ¾ hour, later thoroughly washed and planted in garden soil the first of June, produced plants with viable seeds the first of August. Plots treated with a rather heavy application of sulfur were covered the second spring with a large number of seedlings. Hegi (23) reports that the seed may be viable in the soil for 22 years.

SEEDLINGS

From the middle of April to the end of the season, depending upon the soil moisture, the heart-shaped cotyledons

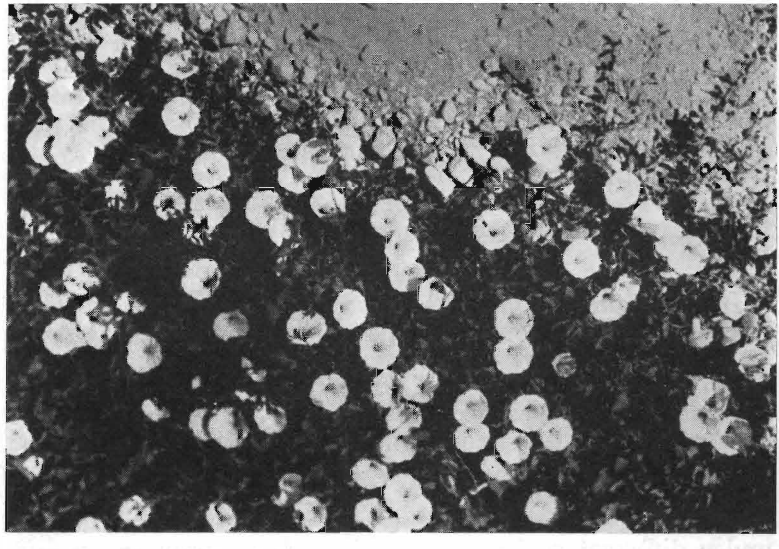

Fig. 3. The bell-shaped flowers of the European bindweed are conspicuous. During hot and dry weather, seed setting is abundant.

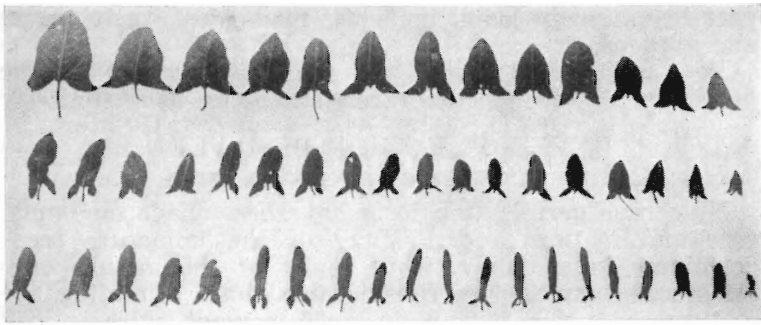

Fig. 4. The leaves of the European bindweed vary considerably in size and general appearance, depending upon the evaporating environment.

of the seedlings may be noticed in any infested area. The seed leaves are usually about 6 mm. wide and 8 mm. long and wider at the tip than at the base. In the latter part of June, 1933, more than 2,000 seedlings were found on an area of a square rod on the Scott farm near Hawarden.

Only a few of the seeds of the European bindweed, collected the current year and placed in the soil in a long slender box, germinated. The germination was rapid in that the cotyledons were above the ground within 10 days. The bud between the cotyledons produced a cluster of shoots. The leaves of these shoots were usually smaller, somewhat curved, with characteristic projecting basal tips and blunt apices. The main root, an extension of the radicle, developed rapidly. The main roots were 30 to 45c m. in length. There were several lateral roots and a number of finer roots. Irmisch (25) in his studies has found that in the spring of the second year the main root may be 1 to 4 feet in length. Buds developed in the upper portions of the root, and the following year shoots were readily formed. Usually no flowers are produced the first year.

MATURE PLANTS

In Iowa the European bindweed is much later in coming into active growth in the spring than leafy spurge (8). The early growth, of course, is dependent upon the depth from which the rhizomes must develop. In the spring of 1935, the tips were showing through the ground on April 22 in the undisturbed fields at Cherokee, Iowa. Where the ground was plowed in the fall, the aerial shoots appeared much later.

There is considerable difference in the size of the leaves under different moisture conditions. Where the ground is hard, as in the case of paths and roads, the leaves are

small and inconspicuous. Where there is sufficient moisture, the leaves and stems are much larger. The leaves of European bindweed growing in plots treated with ammonium thiocyanate[2] was about three times as large as in plots where the bindweed was not given any treatment. The bindweed growing in small grain usually has larger leaves than that found in the open. When the bindweed is shaded, as when it is growing in small grain, the stems twine. In cornfields the bindweed creeps along the ground until considerable shade has been established. During the month of June the bindweed grows very rapidly in Iowa. It comes into full blossom usually toward the latter part of June and may continue to blossom throughout most of July. The cultivation of corn planted on ground infested with the European bindweed retards somewhat the development of the bindweed. When the corn is too tall to be cultivated the bindweed grows very rapidly, and in less than a month's time the ground may be entirely covered with the aerial growth. In such case the blossoming is delayed.

Setting of the seed is dependent largely upon the evaporating environment. In 1930 there was considerable seed produced on the plants in the Hawarden area during July and August. The same year there was much seed produced by the bindweed growing in rye. In 1931, 1932 and 1933 there was very little seed formed. In 1934 large quantities of seed were formed in soybeans drilled in rows. In 1935 the bindweed seed crop was comparatively light in northwestern Iowa, but at Menno, South Dakota, where it was much drier than at Hawarden, large quantities of seed were obtained. It has been noticed that under relatively dry conditions when there is good seed setting on alfalfa, bindweed seeds are produced in large quantities. There are usually four seeds in each capsule, but sometimes all do not develop. When the flower is fertilized it loses its erect or horizontal position and bends downward. The capsule wall when ripe is easily broken, allowing the seeds to escape.

The bindweed usually grows until killing frost, but in certain areas where the evaporation is high, the vines may become dry and the whole plant dormant. With the advent of rain new shoots come out from the crown.

[2] Ammonium thiocyanate first acts as a herbicide but later becomes a fertilizer. See page 403.

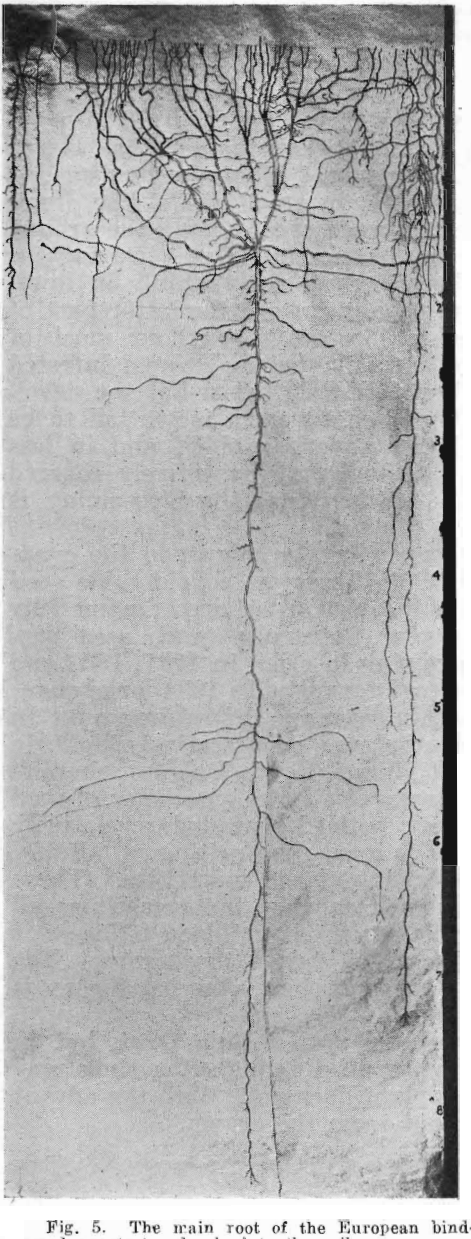

Fig. 5. The main root of the European bindweed penetrates deeply into the soil.

ROOT SYSTEM

The conspicuous part of the root system of the European bindweed is the long tap root. An excavation was made in 1932 at Hawarden, Iowa, to determine the extent of the root system. A drawing of the entire root system (fig. 5) was made at that time. The main tap root extended to a depth of 8 feet 8 inches. There was a large number of feeding roots in the upper 18 inches. At an approximate depth of 18 inches the roots converged more or less, forming a thickened root portion from which the main tap root descended. At the same depth there was found a lateral root extending 20 inches to the right and at the left another lateral root extending horizontally to a distance of 23 inches. At these two points, tap roots had been formed. It is the growth of these laterals which determines the spread of the bindweed year after year. At a depth of 2½ feet lateral roots extend-

ing in a horizontal direction were found. This was also true of roots at a depth of 5½ feet. Here and there, particularly among the younger roots, counter clockwise coils were found. Other excavations were made in 1935; one tap root attained a depth of 20 feet, the ground water level; another root reached a depth of 17½ feet. The tap root of a bindweed grown in an alfalfa field was 12½ feet long; the depth of the alfalfa roots in close proximity to the bindweed was 9 feet.

On July 27, 1935, an excavation was made to determine the amount of root material in a given volume of soil. In a strip 16½ feet long, 1 foot wide and 3 feet deep, the total amount of roots was 465 grams; the first foot had 220 grams, the second foot, 140 grams and the third foot, 105 grams.

Kennedy and Crafts (27), who have made a rather detailed study of the anatomy of the European bindweed in California, state that where the water table is high the tap root may branch at a depth of 2 feet or less, while in other localities it may penetrate to a depth of 10 feet or more before branching profusely. Annual laterals are produced freely and are formed adventitiously in great numbers and permeate the soil in all directions. Most of them die at the end of the season and are replaced by new ones the following year, but at least some of them persist. It is by means of the laterals that spreading in a horizontal direction is accomplished. Shoot buds arising on the horizontal laterals develop rhizomes which upon reaching the surface establish new crowns. The ability to produce buds, together with the food reserves of the roots, favors vegetative reproduction.

Further detail of the anatomy of the European bindweed may be obtained from the article just cited.

SPREAD OF BINDWEED

The spread of the European bindweed may be attributed largely to the presence of bindweed seed in small grain such as oats, barley, wheat and rye. In many cases bindweed seeds may not be mature when the grain is harvested, but before the grain is threshed the seeds will have become dry. Elevators have found it extremely difficult to separate all bindweed seeds from small grain. Shipment of screenings containing bindweed seeds in railroad cars and trucks distribute the bindweed seed en route. In the handling of screenings containing the seeds of this weed, at the terminal points, there is ample opportunity for the seeds to germinate and the plants to develop. Oswald (35)

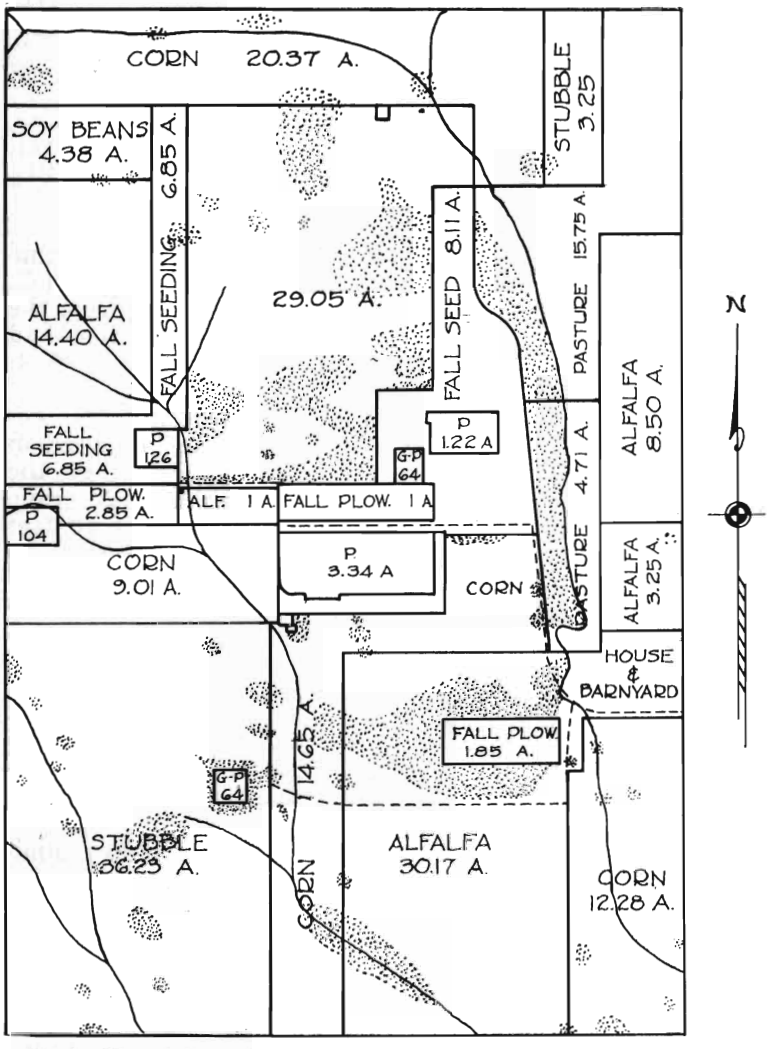

Fig. 6. Plan of the Walter Scott farm at Hawarden, Iowa, in 1935, showing the distribution of the European bindweed. The 1-square-rod plots are included in the areas marked "P."

showed that the seeds of the bindweed may pass through the digestive tract of a horse without much damage. Of 1,000 seeds, 127 were recovered intact; 19 percent of these, upon scarification, germinated.

A bindweed area may also increase in size year by year through lateral roots and underground stems.

EXPERIMENTAL WORK

In 1930 the Association of County Agents of Northwest Iowa became alarmed over the prevalence and spread of the European bindweed and petitioned the Experiment Station for experimental work on the control of this weed. In response to this request, there was established on the Walter Scott farm (fig. 6) 3½ miles northeast of Hawarden, a series of experiments involving both chemical and cultural treatments.

From 1930 to 1934, 380 1-square-rod plots were laid out in heavily infested bindweed areas on the Scott farm. The farm is gently rolling, with some portions of it subject to erosion.[3] A deep ditch traverses the center of the farm and another runs through the pasture. The rotation usually practiced had been 2 years of corn and 1 of small grain. Although approximately 40 acres of alfalfa were grown each year, no regular rotation with alfalfa had been followed. The farm had been in several hands during the 20 years previous to 1930 and its state of tilth had become somewhat low. In 1930 there were more than 80 acres of European bindweed on this farm.

European bindweed was confined for the greater part, to the center of the farm. There were, of course, a number of scattered patches. In a number of plots there was leafy spurge.

The 1-square-rod plots used in the experimental studies were in corn at the time they were established. Plots 1 to 123 were in corn in 1939, plots 124 to 242 in oats in 1930, while the remaining plots were in rye the year before they were used for 1932 investigations. Each 1-square-rod plot was separated from the adjoining plot by a distance of 3½ feet, thus reducing the border effect. The ground had been given the usual preparation required for the growing of corn. Several field plots of various sizes which had had corn or small grain upon them were also used.

During the first year particular attention was given to the use of herbicides. At that time, sodium chlorate,

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[3] Thanks are due Walter Scott of Hawarden, who permitted the free use of all the land that was desired and also furnished much of the equipment used in the farm operations. The French Lumber Co. furnished a building which has been used as a laboratory and for the storage of chemicals and supplies. Rex Conn, H. C. Aaberg and H. S. Nicol, county agents of Sioux County since 1930, have given material assistance in conducting the experiments. The Hawarden Chamber of Commerce has assisted in the Field Day demonstrations which have been held once a year. The City Council of Hawarden and the Hawarden Board of Education provided laboratory space and quarters. During the seasons 1932 and 1934, Ben C. Helmick assisted with the experimental work up to the time of his death. The author is grateful to Dr. I. E. Melhus for his interest at all times in the work and for his aid in preparing this manuscript.

"Atlacide," C. K. (creosote 10 parts, kerosene 90 parts), sulfuric acid, iron sulfate, hypochlorite of lime, borax and zinc sulfate were used. In 1931 ammonium thiocyanate and salt were added to the list. In 1932 plots were treated with sodium chlorate, kainite, chloron, ammonium thiocyanate and sodium chloride. The herbicides were generally applied to the weed foliage by means of a wheelbarrow sprayer. For the larger areas a power sprayer was employed.

Crafts (18) has obtained better results when the sodium chlorate solution was slightly acid. It was known, too, that the Chipman Chemical Company, Bound Brook, New Jersey, added a small amount of glue to the Atlacide. The purpose of the glue was to make the solution adhere to the leaves a little longer. Bakke (9) recommended adding glue and sulfuric acid[4] to a sodium chlorate spray in eradicating such weeds as leafy spurge.

It was, of course, realized at the outset that the use of chemicals in the eradication of weeds is expensive. For this reason considerable attention was given to securing additional information about cultural practices which might render material assistance in the control or the eradication of the bindweed. Various competitive crops such as millet, sudan grass, cane, soybeans and alfalfa were used. Such practices as plowing, fallowing, surface cultivation and regular hoeing were investigated.

The utility of sheep and hogs in the eradication of the European bindweed became a part of the program in 1931.

CHEMICAL TREATMENTS

SODIUM CHLORATE SOLUTION

Sodium chlorate applied in the form of a spray has been extensively used in the eradication of perennial weeds. The literature has been presented in another publication (9).

In 1930, 36 1-square-rod plots, for the greater part heavily infested with European bindweed, were sprayed with sodium chlorate, at different times throughout the growing season from June 26 until Sept. 18. The spray was distributed so as to wet all aerial parts of the bindweed. Three plots were used as controls. The infestation on May 29, 1931, ranged from 0 to "medium."

A detailed statement giving the number of sodium chlorate treatments, the subsequent infestation and subsequent

[4] Where power sprayers are equipped with porcelain-lined cylinders it may be advisable to leave out the acid as there is apt to be a scarring of the porcelain surface. The glue will not have any deleterious effect.

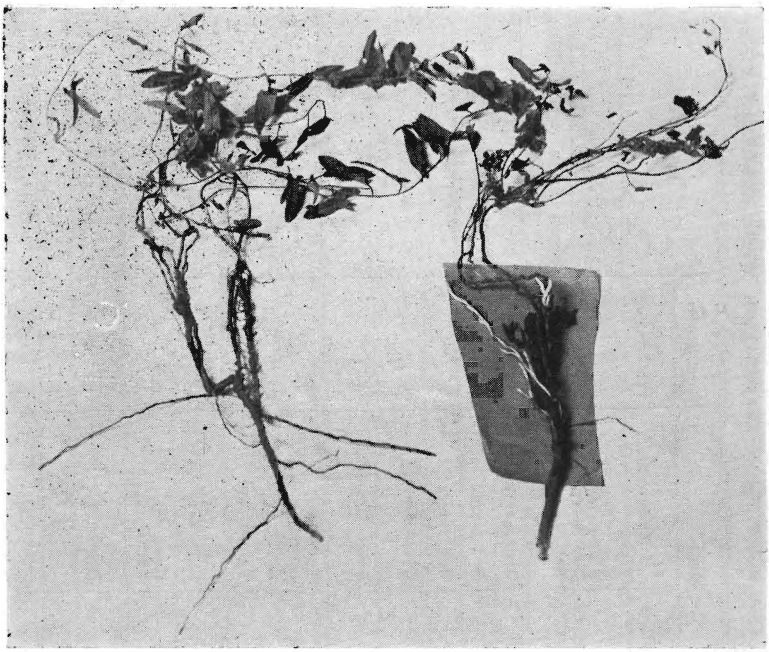

Fig. 7. The older roots are often hard to kill even with such herbicides as sodium chlorate.

treatments, is given in table 1. It is found that one application of sodium chlorate in 1930 did not completely eradicate the European bindweed (plots 2, 4, 5, 47, 83, 84, 101, 108, 111, 112, 114, 146, 147, 148, 149, 154, 162, 212). The marked killing action obtained from the one spraying of sodium chlorate in plots 111 and 112 must be looked upon as exceptional. The heavy growth of other weeds along with a gentle sprinkle of rain may have increased the herbicidal action.

Two sprayings of sodium chlorate applied to European bindweed in 1 year produced better and more consistent results than where only one application was made (plots 6, 41, 42, 44, 49, 51, 52, 82, 96, 98, 100, 124, 134, 240, 243, 247, 250, 252, 254, 256, 258, 321, 322, 326, 330, 333, 337, 339). Of the 27 plots sprayed twice in 1932 with sodium chlorate, eight (240, 245, 328, 332, 333, 337, 338, 339) had no bindweeds the following year; three plots (244, 246, 331) had only one bindweed, while the remaining plots, with the exception of No. 321, had "few" bindweeds.

There was apparently no particular benefit derived from cutting off the vegetative growth before applying sodium chlorate (plots 46, 49).

TABLE 1. TREATMENTS WITH SODIUM CHLORATE SPRAY AND SUBSEQUENT INFESTATION WITH EUROPEAN BINDWEED.

Plot no.	1930	1931		1932		1933*	Remarks
	Treatment	Infestation	Treatment	Infestation	Treatment	Infestation	
2	$NaClO_3$	Medium**‡	Hoed (12)***	Few	Alsike clover	Some	No bindweed in 1934.
3	No treatment	Heavy		Heavy	$NaClO_3$	36	Treated with dry $NaClO_3$; no bindweed in 1934.
4	$NaClO_3$	Light	$NaClO_3$(2)	1	Alsike clover	18	
5	$NaClO_3$	Light	$NaClO_3$(2)	2	Red clover	11	
6	$NaClO_3$(2)	Light	Hoed (4)	0	Red clover	3	
7	$NaClO_3$(3)	0	$(NH_4)_2SO_4$— 2 lbs.	0	Sweet clover	0	
8	$NaClO_3$(2) $NaClO_3$ (dry)	0	$(NH_4)_2SO_4$— 1 lb.	0	Sweet clover	0	
9†	$NaClO_3$ $NaClO_3$ (dry) (2)	9		Few	$NaClO_3$(2) Hoed	0	
11	$NaClO_3$ $NaClO_3$ (dry)	Scattered	$NACIO_3$	50	$NaClO_3$(2)	0	Alfalfa light, 1934.
25	$NaClO_3$(2)—sprinkled	16	$NaClO_3$(2)	11	Hoed (4) $NaClO_3$(2)	1	
26	$NaClO_3$(2) CK(10-90)2½ gals.	Scattered	Atlacide (2)	24	Hoed (5) $NaClO_3$(2)	0	
41	$NaClO_3$(2)	Scattered	$(NH_4)_2SO_4$ (2lbs.) Hoed 2	0	Hoed (6)	0	
42	$NaClO_3$(2)	Few	Hoed (3)	0		0	
43	$NaClO_3$(3)	0	Hoed (3)	0		0	

TABLE 1. TREATMENTS WITH SODIUM CHLORATE SPRAY AND SUBSEQUENT INFESTATION WITH EUROPEAN BINDWEED—Continued.

Plot no.	1930	1931		1932		1933	Remarks
	Treatment	Infestation	Treatment	Infestation	Treatment	Infestation	
44	$NaClO_3$(2) $NaClO_3$ (dry)	0	Hoed (3)	3	Hoed (3) $NaClO_3$(2)	0	
46	Ground clean to 7-8 $NaClO_3$ $NaClO_3$ (dry) (2)	Some	Hoed (5)	3	$NaClO_3$(2)	0	
47	$NaClO_3$	Light	$NaClO_3$(2)	47	Hoed (2) $NaClO_3$(2)	0	
48	No treatment Green weight determined 7-8.	Heavy	$NaClO_3$(2)	60	Hoed (3) $NaClO_3$(2)	0	
49†	$NaClO_3$ (2)	Light	Tops cut off $NaClO_3$	10	Hoed $NaClO_3$(2)	1	
50	$NaClO_3$(2)	Few	$NaClO_3$	47	Hoed (2) $NaClO_3$(2)	1	Alfalfa fair 1934; 21 seedlings, 1933, hoed.
51	$NaClO_3$(2)	3	Hoed (2) $NaClO_3$	34	$NaClO_3$(2)	0	
52	$NaClO_3$(2)	0	Hoed (2)	16	Hoed (2) $NaClO_3$(2)	0	
82	$NaClO_3$(2)	Few	Hoed (3) $NaClO_3$	9	$NaClO_3$(2)	3 seedlings	Alfalfa light.
83	$NaClO_3$	Light	$NaClO_3$(2)	29	$NaClO_3$(2)	2 seedlings	
84	$NaClO_3$	Light	$NaClO_3$	21	$NaClO_3$	0	
94	No treatment	Heavy	No treatment	Heavy	$NaClO_3$	2 seedlings	7 bindweeds, 1933.
96	$NaClO_3$(2)	Light	$NaClO_3$(2)		$NaClO_3$(2)	0	
97	$NaClO_3$(2)	Few		11	$NaClO_3$(2)	5 seedlings	
98	$NaClO_3$(2)	Few	$NaClO_3$(2)	11	$NaClO_3$(2)	21 seedlings	
100	$NaClO_3$(2)	Few	$NaClO_3$(2)	15	Hoed (3) $NaClO_3$(2)	8 seedlings	

TABLE 1. TREATMENTS WITH SODIUM CHLORATE SPRAY AND SUBSEQUENT INFESTATION WITH EUROPEAN BINDWEED—Continued.

Plot no.	1930	1931		1932		1933	Remarks
	Treatment	Infestation	Treatment	Infestation	Treatment	Infestation	
101	$NaClO_3$	Few	Hoed (2) $NaClO_3$	59	Hoed (3) $NaClO_3$(2)	8 seedlings	
108	$NaClO_3$	Light	Hoed (5)	11	Hoed $NaClO_3$(2)	0	
111	$NaClO_3$	0		0		0	Alfalfa very good.
112	$NaClO_3$	0	Hoed (2) CK	0		0	Alfalfa good.
114	$NaClO_3$	Some	$NaClO_3$(2)	35	$NaClO_3$(2)	0	
117	No treatment	Heavy	$NaClO_3$(3)	Light	$NaClO_3$(2)	1 seedling	No bindweed in 1934.

	1931	1932		1933		1934	
123	No treatment	Heavy		Heavy	47 hoed (2) alfalfa	0	Alfalfa fair.
124	$NaClO_3$(2)	Scattered	$NaClO_3$(2)	Few	5 hoed (2) alfalfa	0	Alfalfa fair.
125	$NaClO_3$(2)	Scattered	Hoed (2) $NaClO_3$(2)	Few	2 hoed(2) alfalfa	0	Alfalfa fair, 1934.
126	$NaClO_3$(2)	Scattered	Hoed (2) $NaClO_3$(2)	1	Hoed (2) alfalfa	0	One bare spot; alfalfa fair, 1934.
127	$NaClO_3$(2)	Scattered	Hoed (2) $NaClO_3$(2)	59 seedlings	Hoed Alfalfa	0	Two-thirds plot bare 1934.
128	$NaClO_3$(2)	Scattered	Hoed (2) $NaClO_3$(2)	32 seedlings	Hoed Alfalfa	0	Alfalfa fair, 1934.

TABLE 1. TREATMENTS WITH SODIUM CHLORATE SPRAY AND SUBSEQUENT INFESTATION WITH EUROPEAN BINDWEED—Continued.

Plot no.	1931	1932		1933		1934	Remarks
	Treatment	Infestation	Treatment	Infestation	Treatment	Infestation	
129	$NaClO_3$(2)	Few	Hoed (2) $NaClO_3$(2)	12 seedlings	Hoed	0	Alfalfa poor, 1934.
130	$NaClO_3$(2)	Few	Hoed (2) $NaClO_3$(2)	14 seedlings	Hoed (2)	0	Alfalfa fair.
131	$NaClO_3$(2)	Few	Hoed (2) $NaClO_3$(2)	28 seedlings	Hoed	0	Alfalfa poor.
132	$NaClO_3$(2)	Few	Hoed (2) $NaClO_3$(2)	22 seedlings	Hoed	0	Alfalfa poor.
133	$NaClO_3$(2)	Scattered	Hoed (2) $NaClO_3$(2)	6 seedlings	Hoed	0	Alfalfa poor.
134	$NaClO_3$(2)	Few	Hoed (2) $NaClO_3$(2)	3 seedlings	Hoed (2)	0	Alfalfa poor.
142	$NaClO_3$(2)	Few	Hoed $NaClO_3$(3)	0	Fallowed Alfalfa	0	
143	No treatment	Heavy		Heavy	Fallowed Alfalfa	Some	
144	$NaClO_3$ $NaClO_3$ (dry)	Few	Hoed $NaClO_3$(3)	1	Hoed	0	
145	$NaClO_3$ $NaClO_3$ (dry)	Few	Hoed $NaClO_3$(2)	1	Hoed	0	
146	$NaClO_3$	Few	Hoed $NaClO_3$(2)	5 seedlings	Barley Hoed Alfalfa	0	Barley seeded 1933. Poor.
147	$NaClO_3$	39	Hoed $NaClO_3$(2)	7 seedlings	Barley Hoed Alfalfa	0	Alfalfa good 1934.
148	$NaClO_3$	Few	Hoed $NaClO_3$(2)	0	Barley Alfalfa	0	
149	$NaClO_3$	Few	Hoed $NaClO_3$(2)	5 seedlings	Barley Alfalfa	0	
153	No treatment	Light		Heavy	$NaClO_3$ Alfalfa	9	Alfalfa light.

TABLE 1. TREATMENTS WITH SODIUM CHLORATE SPRAY AND SUBSEQUENT INFESTATION WITH EUROPEAN BINDWEED—Continued.

Plot no.	1931	1932		1933		1934	Remarks
	Treatment	Infestation	Treatment	Infestation	Treatment	Infestation	
154	$NaClO_3$	Light	Hoed $NaClO_3$(2)	12 seedlings	Barley Hoed Alfalfa	0	
155	$NaClO_3$	Light	Hoed $NaClO_3$(2)	14 seedlings	Barley Hoed Alfalfa	1	
156	$NaClO_3$	Few	Hoed $NaClO_3$(2)	30 seedlings	Barley Hoed Alfalfa	0	Alfalfa good.
157	$NaClO_3$	Light	Hoed $NaClO_3$(2)	15 seedlings	Barley Alfalfa	0	
158	$NaClO_3$	Few	Hoed $NaClO_3$(2)	Few	Fallowed Alfalfa	5	
159	$NaClO_3$	Light	Hoed $NaClO_3$(2)	Few	Hoed	7	Fallowed, alfalfa, 1934.
160	$NaClO_3$	Light	Hoed $NaClO_3$(3)	7	Hoed	5	Fallowed, alfalfa, 1934.
161	$NaClO_3$	Light	Hoed $NaClO_3$ (3)	0	Cultivated	4	Fallowed, alfalfa, 1934.
192	$NaClO_3$	Few	Hoed $NaClO_3$ (2)	167 seedlings	Alfalfa	4	Alfalfa fair, 1934.
203	$NaClO_3$ Sulfur $NaClO_3$ (dry)	Few	Hoed (2) $NaClO_3$	8	Cultivated	4	Fallowed, alfalfa, 1934.
212	$NaClO_3$	Few	Hoed (2) $NaClO_3$	0	Barley Alfalfa	1	

TABLE 1. TREATMENTS WITH SODIUM CHLORATE SPRAY AND SUBSEQUENT INFESTATION WITH EUROPEAN BINDWEED—Continued.

	1932	1933		1934		1935	
240	$NaClO_3$(2)	0		4	Hoed Fallowed Alfalfa	0	
242	$NaClO_3$(3)	Few		Few	Fallowed Alfalfa	Few seedlings	Individual plants treated with Oldbury weed killer.
243	$NaClO_3$(2)	14	Hoed Cultivated	8	Fallowed Alfalfa	0	Alfalfa good.
244†	$NaClO_3$(2)	1	Hoed Cultivated	0	Fallowed Alfalfa	0	Alfalfa good.
245†	$NaClO_3$(2)	0	Hoed Cultivated	0	Fallowed Alfalfa	0	
246†	$NaClO_3$(2)	1	Hoed Cultivated	0	Fallowed Alfalfa	0	
247†	$NaClO_3$(2)	7	Hoed Cultivated	0	Fallowed Alfalfa	0	
248	No treatment	Heavy	Hoed Cultivated	8	Fallowed Alfalfa	5	Alfalfa good.
249	$NaClO_3$(3)	3	Hoed Cultivated	6	Fallowed Alfalfa	0	
250	$NaClO_3$(2)	19	Hoed Cultivated	4	Fallowed Alfalfa	0	
251	$NaClO_3$(3)	4	Hoed Cultivated	1	Fallowed Alfalfa	Few	

TABLE 1. TREATMENTS WITH SODIUM CHLORATE SPRAY AND SUBSEQUENT INFESTATION WITH EUROPEAN BINDWEED—Continued.

Plot no.	1932	1933		1934		1935	Remarks
	Treatment	Infestation	Treatment	Infestation	Treatment	Infestation	
252	$NaClO_3$(2)	10	Hoed Cultivated	14	Fallowed Alfalfa	Few	
253	$NaClO_3$(3)	15	Hoed Cultivated	10	Fallowed Alfalfa	0	
254	$NaClO_3$(2)	8, few seedlings	Hoed Cultivated	14	Fallowed Alfalfa	0	Alfalfa good.
255	$NaClO_3$(3)	6, many seedlings	Hoed Cultivated	15	Fallowed Alfalfa	0	Alfalfa good.
256	$NaClO_3$(2)	10, many seedlings	Hoed Cultivated	Few	Fallowed Alfalfa	0	Alfalfa good.
257†	$NaClO_3$(2)	7, few seedlings	Hoed Cultivated	2	Fallowed Alfalfa	0	Alfalfa good.
258†	$NaClO_3$(2)	3	Hoed	0	Fallowed Alfalfa	0	Alfalfa good.
321	$NaClO_3$(2)	Light	Cultivated (2)	Few	Buckwheat	7	Sudan grass; plowed, 1935
322	$NaClO_3$(2)	Few	Barley $NaClO_3$	Scattered	Buckwheat $NaClO_3$	4	Sudan grass; cut, plowed 1935.
323	$NaClO_3$(2)	Few	Barley $NaClO_3$	Scattered	Buckwheat $NaClO_3$	9	Sudan grass; plowed, 1935.
324	$NaClO_3$(2)	Few	Barley $NaClO_3$	Scattered	Buckwheat $NaClO_3$	Few	Sudan grass; plowed, 1935.
325	$NaClO_3$(2)	3	Barley $NaClO_3$	Few	Buckwheat $NaClO_3$	12	Sudan grass; plowed, 1935.

TABLE 1. TREATMENTS WITH SODIUM CHLORATE SPRAY AND SUBSEQUENT INFESTATION WITH EUROPEAN BINDWEED—Continued.

Plot no.	1932	1933		1934		1935	Remarks
	Treatment	Infestation	Treatment	Infestation	Treatment	Infestation	
326	$NaClO_3$(2)	12	Barley $NaClO_3$	3	Buckwheat $NaClO_3$	3	Sudan grass; plowed, 1935.
327	$NaClO_3$(2)	Few	Barley $NaClO_3$	2	Buckwheat $NaClO_3$	0	Sudan grass poor, 1935.
328	$NaClO_3$(2)	0	Barley	0	Buckwheat $NaClO_3$	1	Sudan grass; plowed, 1935.
329	No treatment	Heavy	Barley	Heavy	Buckwheat $NaClO_3$	Some	Sudan grass.
330	$NaClO_3$(2)	2	Barley $NaClO_3$	2	Buckwheat $NaClO_3$	4	Sudan grass; cut, plowed, 1935.
331	$NaClO_3$(2)	1	Barley $NaClO_3$	0	Buckwheat $NaClO_3$	0	Sudan grass; cut, plowed, 1935.
332	$NaClO_3$(2)	0	Barley	0	Sudan grass	0	Sudan grass; cut, plowed, 1935.
333†	$NaClO_3$(2)	0	Barley	0	Sudan grass	0	Sudan grass; good, 1935.
337	$NaClO_3$(2)	0	Barley	0	Sudan grass	0	Sudan grass; good, 1935.
338	$NaClO_3$(2)	0	Barley $NaClO_3$	0	Sudan grass	0	Sudan grass.
339	$NaClO_3$(2)	0	Barley $NaClO_3$	0	Sudan grass	0	Sudan grass.

*All 1930 plots seeded to alfalfa, August, 1933.

**Explanation of the terms used for the extent of bindweed infestation when the exact number of plants is not given:
Heavy—ground covered, entirely shaded.
Medium or fairly heavy—between light and heavy.
Light—ground partially covered, other vegetation visible or considerable; more than 50 plants per square rod.
Scattered—between 25 and 50 plants on a square rod.
Few—less than 25 plants on a square rod.

***The number placed in parenthesis indicates the number of treatments; where no number is present, it is understood that only one treatment was made.

†"Light" infestation of European bindweed.

‡Record made the second week in June.

Bindweeds appearing the year after treatment with a herbicide should be given two treatments the current year to insure extermination (plots 4, 11, 84, 322, 323, 324).

Frequent hoeing following sodium chlorate applications generally assisted in the elimination of the bindweed (plots 6, 42, 46, 82, 108, 243).

Three spray treatments (plots 7, 43) or two spray and one dry treatment (plots 8, 44) in 1930 eliminated all European bindweed in one season. Five plots (242, 249, 251, 253, 255) sprayed three times in 1932 showed the presence, respectively, of "few," 3, 4, 15 and 6 bindweeds in 1933. On the basis of these results there appears to be no object in giving more than two sodium chlorate sprays in one season.

Barley seeded the following spring (plots 146, 153, 156, 322, 323, 324, 331, 333, 339) after the plots were chlorated failed to develop. Alsike clover (plots 2, 4), red clover (plots 5, 6) and sweet clover[5] (plots 7, 8) were tolerant to small amounts of sodium chlorate in the soil.

Buckwheat (plots 322, 325, 326, 330) has not proved to be an effective smother crop in completing the process of exterminating bindweed. Sudan grass (plots 321, 333, 337, 338, 339) has given better results. The seedlings are of considerable concern, on areas previously treated with sodium chlorate, and if undisturbed will produce reinfestation (plots 127, 134, 146, 147, 159, 192, 203). The seedlings may be eliminated through cultivation and subsequent seeding of alfalfa. It is obvious that to spring seed small grain upon ground infested with European bindweed does not give the grain a chance for successful competition.

The use of a fertilizer such as ammonium sulfate $(NH_4)_2SO_4$ (plots 7, 8, 41) upon plots treated with sodium chlorate should be given further experimentation before conclusions are drawn.

Alfalfa, also exceedingly tolerant to sodium chlorate, is probably the best crop to use upon ground which has been previously treated with sodium chlorate. All 1930-1931 plots were seeded to alfalfa in August, 1933, and the growth on the majority was normal. No bindweed has been found since on these plots.

SUCCESSFUL TREATMENT OF LARGE PLOTS

On Sept. 2, 1931, a strip of ground 1 rod wide and 50 rods long, heavily infested with the European bindweed, which had been in winter rye in 1930 and planted to corn

[5] Sweet clover has proved to be exceedingly tolerant to sodium chlorate. Roadsides heavily infested with European bindweed and sprayed heavily in October have carried a dense growth of sweet clover the following spring.

in 1931, was sprayed with sodium chlorate without cutting the corn. Oats grown on this ground in 1932 were harvested and the ground immediately plowed. On July 17 sorghum was heavily seeded with the use of a grain drill. As a result of this treatment the bindweed infestation was reduced from "heavy" to "few."

In 1932, on Oct. 10-11, a 7-acre tract, upon which a poor crop of soybeans had been harvested and which was heavily infested with bindweeds, was sprayed with sodium chlorate. A heavy crop of millet and cane, the next year, practically eliminated the bindweeds.

On June 28, 1932, and July 2, 1932, two European bindweed areas about ¼ acre in extent, growing in oats, were sprayed with sodium chlorate. As a result of this one spraying there were only a "few" bindweeds left. During the first part of September the two areas were given the second spray. These two treatments eradicated the bindweeds.

In 1934, a ½-acre patch of European bindweed was found north of the Agronomy farm at Ames. In the fall of that year the ground was plowed and seeded to winter rye. On July 5, 1935, the area was sprayed with sodium chlorate so that the bindweed and rye were thoroughly wetted. During the early part of September, the secondary growth, approximately 90 percent less than when the first spray was applied, was given the second spray. On May 19, 1936, only two small bindweeds along with a few yellow colored seedlings were present. No bindweed has since been found on this area.

DRY SODIUM CHLORATE

The application of sodium chlorate in the dry form directly to the soil where weed infestation is present was advocated by Åslander (4), Schafer, Lee and Neller (39), Loomis, Bissey and Smith (32). The use of sodium chlorate in the dry form entails less fire hazard than use in the spray form. It is, of course, not necessary to purchase expensive and comparatively short lived spraying equipment. Kiesselbach, Petersen and Burr (29) state that 320 pounds or more of sodium chlorate per acre, applied with a grain drill, were effective in eradicating the European bindweed in Nebraska. In 1935, at Hawarden, the dry salt was placed directly in the plow furrow with good results. A number of tests using sodium chlorate in the dry form were made at Hawarden beginning in 1930. A summarized chronological history of the treatments with the dry form of sodium chlorate is given in table 2.

TABLE 2. DETAILS OF TREATMENTS WITH DRY SODIUM CHLORATE AND SUBSEQUENT INFESTATION WITH EUROPEAN BINDWEED.

Plot no.	1930	1931		1932		1933	Remarks
	Treatment	Infestation	Treatment	Infestation	Treatment	Infestation	
10*	$NaClO_3$(3)** 4 lbs.	Scattered	Hoed (5)	Few	Hoed (2) $NaClO_3$(3)	0	Alfalfa seeded August, 1933.
12	$NaClO_3$ ⅝ lb.	Heavy	$NaClO_3$(2) (spray)	50	Hoed (3) $NaClO_3$(2) (spray)	0	Alfalfa seeded August, 1933.
24	$NaClO_3$(2) 3½ lbs.	Scattered	Hoed (3) $NaClO_3$ (spray)	0	$NaClO_3$(2) (spray)	0	Alfalfa seeded August, 1933.
58	$NaClO_3$ 1 lb.	Heavy	$NaClO_3$(3) (spray)	0	$NaClO_3$(2) (spray)	0	One-fourth of plot bare.
54	$NaClO_3$ 1 lb.	Light	Atlacide (2) (spray)	Few	$NaClO_3$(2) (spray)	1	One-fourth of plot bare.
85	$NaClO_3$ 2 lbs. $NaClO_3$ (spray) 2 lbs.	Scattered	$NaClO_3$(2) (spray)	Few	Hoed (2) $NaClO_3$(2) (spray)	5 seedlings	One-fourth of plot bare.
86	$NaClO_3$(2) 3 lbs.	Scattered	H_2SO_4 $NaClO_3$ (spray)	Few	Hoed (2) $NaClO_3$(2) (spray)	5 seedlings	Alfalfa spotted.
109	$NaClO_3$ 2½ lbs.	Light	Hoed (2)	0		0	Alfalfa good.
122	$NaClO_3$ 2½ lbs.	Heavy	Hoed (2) $NaClO_3$ (spray)	Scattered	$NaClO_3$(2) (spray)	15 seedlings	No bindweed in 1935.

TABLE 2. DETAILS OF TREATMENTS WITH DRY SODIUM CHLORATE AND SUBSEQUENT INFESTATION WITH EUROPEAN BINDWEED—Continued.

	1931	1932		1933		1934	
238*	$NaClO_3$ 2 lbs.	Few	Hoed (2) $NaClO_3$ (spray)	Few	Hoed	Few	Fallowed, seeded to alfalfa, 1934.
239*	$NaClO_3$ 2 lbs.	Few Many seedlings	Hoed (2) $NaClO_3$ (spray)	Scattered	Hoed	Few	Fallowed, seeded to alfalfa, 1934.
361*	$NaClO_3$ 2 lbs.	Few	Barley $NaClO_3$ (spray)	Scattered	Field peas, cane, alfalfa	8	Alfalfa fair.
362*	$NaClO_3$ 2 lbs.	Few	Barley $NaClO_3$ (spray)	Few	Soybeans Alfalfa	28	Soybeans very poor. Alfalfa poor.

*Light infestation of European bindweed.
**The number placed in parenthesis indicates the number of treatments; where no number is present, it is understood that only one treatment was made.

The nine plots treated in 1930 with dry sodium chlorate in amounts ranging from 5/8 to 4 pounds per square-rod plot had "scattered" to "heavy" infestations of European bindweed the following year. It became necessary to hoe or treat again in 1931 and 1932. The alfalfa seeded in 1933 was generally spotted and poor. Applications of 5/8 pound to 1 pound were probably too light. The bindweeds of the 1931 plots (238, 239, 361, 362) were reduced to "few" the next season, and in 1932 the number of plants ranged from "few" to "scattered." The results of the dry applications of sodium chlorate were somewhat inconsistent, and this method could not be considered as effective as spraying.

ATLACIDE SOLUTION

"Atlacide" is a commercial weed killer manufactured by the Chipman Chemical Company, Bound Brook, New Jersey. This patented herbicide, in addition to sodium chlorate, contains ingredients which decrease the fire hazard. Prior to 1935, Atlacide contained principally sodium chlorate and calcium chloride, a hygroscopic salt. The Atlacide used in the present investigation was the mixture manufactured prior to 1935 and should not be confused with the Atlacide on the market today, which differs in formula and effectiveness as an herbicide. The Atlacide solution usually of a concentration of 1 pound to a gallon of water was applied to the leaf surface so that all parts were dripping wet. Usually it required 3 gallons of solution to the square rod where the bindweed was "heavy." The data for the Atlacide treatments have been tabulated in table 3.

Of the 24 European bindweed plots given one treatment of Atlacide in 1930 and 1931, the infestation the following year ranged from "few" to "heavy"; four of the 1930 plots (14, 95, 105, 110) had "light" infestations. Eight of the 1931 plots, (167, 168, 169, 170, 180, 182, 183, 211) had "few" plants, nine (164, 165, 166, 172, 173, 174, 175, 193, 204) "scattered" and one (181) "light." Two treatments in 1930 and 1931 produced results which were only a little better than where only one treatment was given. Plots (58, 90, 91, 136, 138, 139, 140, 141) had "few" plants, one (137) "cattered," five (56, 57, 59, 88, 89) "light" and one (135) "heavy." On plot 15, all the bindweeds were killed. Of the three plots given three Atlacide treatments (7 5/8 pounds) in 1930, two plots (16, 17) showed complete elimination, and plot 18, given one spray and two dry treatments, (7 5/8 pounds) had "few" plants remaining in 1931.

TABLE 3. DETAILS OF EXPERIMENTS WITH ATLACIDE SPRAY AND SUBSEQUENT INFESTATION WITH EUROPEAN BINDWEED.

Plot no.	1930	1931		1932		1933	Remarks
	Treatment	Infestation	Treatment	Infestation	Treatment	Infestation	
13	Atlacide	Heavy	Atlacide (2)**	Few	Hoed (2) Atlacide (2)	0	Alfalfa seeded, August, 1933.
14*	Atlacide	Light	Atlacide (2)**	Few	Hoed (2) Atlacide (2)	0	Alfalfa good.
15*	Atlacide (2)	0	Hoed $(NH_4)_2SO_4$ 2 lbs.	0	Sweet clover	0	Alfalfa seeded, 1933; good.
16	Atlacide (3)	0	Hoed (2)	0	Alfalfa	0	Alfalfa fair.
17	Atlacide (3)	0	Hoed (2)		Alfalfa	0	Alfalfa good.
18	Atlacide Atlacide (2) (dry) 7 lbs.	Few	Hoed (2)	Few	Hoed Alfalfa	Few	47 bindweeds, 6-2-34.
21	No treatment	Heavy	No treatment	Heavy	$NaClO_3$	0	Four bindweeds in 1934.
56	Atlacide (2)	Light	Hoed Atlacide	Scattered	Hoed (2) $NaClO_3$(2)	7	Alfalfa seeded, August, 1933.
57	Atlacide (2)	Light	Hoed Atlacide	Scattered	Hoed (2) $NaClO_3$(2)	6 seedlings	Alfalfa seeded, August, 1933.
58	Atlacide (2)	Few	Hoed (3)	Few	Hoed (2) $NaClO_3$(2)	3 seedlings	Alfalfa seeded, August, 1933.
59*	Atlacide CK(10-90)	Light	Atlacide (2)	Few	Hoed (2) $NaClO_3$(2)	0	Alfalfa good.
88	Atlacide (2)	Light	$NaClO_3$ H_2SO_4	Light	Hoed (3) $NaClO_3$(2)	0	
89**	Atlacide (2)	Light	H_2SO_4	Light	Hoed (3) $NaClO_3$(2)	1 seedling	Alfalfa good.

TABLE 3. DETAILS OF EXPERIMENTS WITH ATLACIDE SPRAY AND SUBSEQUENT INFESTATION WITH EUROPEAN BINDWEED—Continued.

Plot no.	1930	1931		1932		1933	Remarks
	Treatment	Infestation	Treatment	Infestation	Treatment	Infestation	
90**	Atlacide (2)	Few	Atlacide	Few	Hoed (3) $NaClO_3$(2)	1 seedling	Alfalfa good.
91**	Atlacide (2)	Few	Hoed (2) Atlacide (2)	Few	$NaClO_3$(2)	0	
93	Atlacide (2)	Light	Atlacide (2)	Few	Hoed (3) $NaClO_3$(2)	16 seedlings	One-third plot bare. Alfalfa poor, 1934.
95**	Atlacide	Light	Atlacide $NaClO_3$	Few	$NaClO_3$(2)	0	Alfalfa fair.
102**	Atlacide	Few	Hoed (2) Atlacide (2)	Scattered	Hoed (2) $NaClO_3$(2)	17 seedlings	Alfalfa poor. One-half plot bare.
105*	Atlacide	Light	$NaClO_3$ Atlacide	0	$NaClO_3$(2)	6 seedlings	Alfalfa good.
110**	Atlacide	Light	Hoed Hoed (3)	0		0	Alfalfa very good, 1934.

	1931	1932		1933		1934	
135	Atlacide (2)	Heavy	Hoed Atlacide (2)	3 seedlings	Hoed Alfalfa	0	
136	Atlacide (2)	Few	Hoed (3) Atlacide (2)	18 seedlings	Hoed Alfalfa	0	
137	Atlacide (2)	Scattered	Hoed (2) Atlacide (2)	3 seedlings	Hoed Alfalfa	0	Alfalfa poor.
138	Atlacide (2)	Few	Hoed (2) Atlacide (2)	5 seedlings	Hoed Alfalfa	0	Much of plot bare.

TABLE 3. DETAILS OF EXPERIMENTS WITH ATLACIDE SPRAY AND SUBSEQUENT INFESTATION WITH EUROPEAN BINDWEED—Continued.

Plot no.	1931	1932		1933		1934	Remarks
	Treatment	Infestation	Treatment	Infestation	Treatment	Infestation	
139	Atlacide (2)	Few	Hoed (2) Atlacide (2)	4 seedlings	Hoed Alfalfa	0	Alfalfa fair.
140	Atlacide (2)	Few	Hoed (2) Atlacide (2)	4 seedlings	Hoed Alfalfa	0	Alfalfa fair.
141	Atlacide (2)	Few	Hoed (2) Atlacide (2)	3 seedlings	Hoed Alfalfa	0	One-half plot bare, 1934.
162	Atlacide Atlacide (dry)	Scattered	Hoed Atlacide (2)	2	Cultivated	22	Hoed, fallowed, alfalfa, 1934.
163	Atlacide Atlacide (dry	Scattered	Hoed Atlacide (3)	2	Hoed	15	Hoed, fallowed, alfalfa.
164	Atlacide	Scattered	Hoed Atlacide (2)	Few		15	Hoed, fallowed, alfalfa.
165	Atlacide	Scattered	Hoed Atlacide (3)	0		6	Hoed, fallowed, alfalfa.
166	Atlacide	Scattered	Hoed Atlacide (2)	6 seedlings	Barley Hoed Alfalfa	0	Alfalfa fair.
167	Atlacide	Few	Hoed Atlacide (2)	5 seedlings	Barley Hoed Alfalfa	0	
168	Atlacide	Few	Hoed Atlacide (2)	6 seedlings	Barley Alfalfa	0	Alfalfa fair.
169	Atlacide	Few	Hoed Atlacide (3)	19	Hoed Alfalfa	0	Alfalfa good.
170	No treatment	Light		Light	Barley $NaClO_3$ Alfalfa	Few	Alfalfa fair.
171	Atlacide	Few	Atlacide (2)	0	Barley Alfalfa	0	Alfalfa fair.
172	Atlacide	Scattered	Atlacide (2)	92 seedlings	Barley Hoed Alfalfa	0	

TABLE 3. DETAILS OF EXPERIMENTS WITH ATLACIDE SPRAY AND SUBSEQUENT INFESTATION WITH EUROPEAN BINDWEED—Continued.

Plot no.	1931	1932		1933		1934	Remarks
	Treatment	Infestation	Treatment	Infestation	Treatment	Infestation	
173	Atlacide	Scattered	Atlacide (2)	0	Barley Alfalfa	0	Alfalfa fair.
174	Atlacide	Scattered	Atlacide (2)	35 seedlings	Barley Alfalfa	0	Alfalfa light.
175	Atlacide	Scattered	Atlacide (2)	10 seedlings	Barley Alfalfa	4	Alfalfa light.
180	Atlacide	Few	Atlacide (2)	13 seedlings	Hoed	10	Fallowed, alfalfa, 1934.
181	Atlacide	Light	Hoed Atlacide (3)	6	Cultivated	12	Fallowed, alfalfa, 1934.
182	Atlacide	Light	Atlacide (2)	6		4	Fallowed, alfalfa, 1934.
183	Atlacide	Few	Atlacide (2)	8		0	Fallowed, alfalfa, 1934.
193	Atlacide	Scattered	Atlacide (2)	124 seedlings	Barley Alfalfa	0	
204	Atlacide	Scattered	Hoed Atlacide (2)	2		16	Hoed, fallowed, alfalfa, 1934.
211	Atlacide	Few	Hoed Atlacide (2)	Few	Barley Alfalfa	0	Alfalfa good.

*"Light" infestation.
**"Scattered" infestation.

Two Atlacide treatments the second year produced a material reduction in the number of bindweed plants. In the 1931 series (plots 135-141) the remaining bindweeds treated in 1932 were reduced to the point where only seedlings appeared in 1933. Upon cultivation these were easily killed.

The greatest reduction in the number of bindweeds occurred, as in the case with sodium chlorate, with the first Atlacide application. A further reduction occurred with the second spray. Where there were remaining plants the second year, two treatments of Atlacide during the season reduced the number of plants to the point where it was possible to kill the remaining ones by applying the spray or the dry salt directly to the individual plants.

Creosote-kerosene (C. K. 10-90) killed the aerial parts (plot 59) but gave no indication that such a solution could replace the second Atlacide spray. Sulfuric acid (10 percent) (plots 88, 89) apparently had little effect in the eradication of the bindweed.

Cultivation by hoeing, the second and third years, did not appear to have much effect upon bindweeds already established (plots, 56, 58, 91, 110, 135, 162).

The application of ammonium sulfate to areas where the bindweed had been killed by Atlacide or sodium chlorate may have had some effect in establishing better growth conditions for subsequent crops (plot 16).

Areas where the bindweed has been killed by the use of Atlacide may be seeded to alfalfa (table 3) in August of the year after the last treatment. Alfalfa seeded in the spring (plot 18) does not offer the competition that August seeding provides (plot 56). Sweet clover may be grown satisfactorily on ground which has been chlorated the previous year (plot 15). Barley has proved to be highly sensitive to Atlacide or sodium chlorate (plots 166-173). Where it was seeded the second year it did not attain a growth of more than 6 or 8 inches.

DRY ATLACIDE

A series of experiments, planned to determine the effectiveness of Atlacide used dry was made in 1930 and 1931. The plots, for the greater part heavily infested with bindweed, were in corn in 1930 and 1931. Results obtained from scattering the dry Atlacide salt uniformly upon the soil of 15 plots are tabulated in table 4.

The results from the use of dry Atlacide from July to September, 1930, in amounts ranging from $\frac{5}{8}$ pound to 6 pounds per plot were somewhat inconsistent. Six pounds

TABLE 4. DETAILS OF TREATMENTS WITH DRY ATLACIDE AND SUBSEQUENT INFESTATION WITH EUROPEAN BINDWEED.

Plot no.	1930	1931		1932		1933*	Remarks
	Treatment	Infestation	Treatment	Infestation	Treatment	Infestation	
19	Atlacide (3) 6 lbs.	Light	Hoed (4)	Few	Hoed (3) Alfalfa	89	Alfalfa spotted, no bindweed, 1934.
20	Atlacide (2) 4⅛ lbs.	Light	Hoed (6)	Few	Hoed (3) Alsike Clover	89	Few bindweed, 1934.
22*	Atlacide ⅝ lb.	Heavy	$NaClO_3$ (spray) (2)	Few	Hoed (4) $NaClO_3$(2) (spray)	0	
23	Atlacide ⅝ lb.	Heavy	$NaClO_3$ (spray) Atlacide (spray)	Light	Hoed (4) $NaClO_3$(2) (spray)	0	Alfalfa spotted, poor.
60	Atlacide 1 lb. Atlacide (spray)	Light	Atlacide (spray) (2)	Few	Hoed (2) $NaClO_3$(2) (spray)	0	Alfalfa short, brown.
61	Atlacide 2 lbs.	Light	Hoed Atlacide (spray)	Few	Hoed (3) $NaClO_3$(2) (spray)	0	Alfalfa light, spotted.
62	Atlacide 1 lb.	Heavy	Atlacide (spray) (2)	Light	Hoed $NaClO_3$(2) (spray)	1	Alfalfa light, spotted.
87	Atlacide (2) 5 lbs.	Light	Atlacide (spray) H_2SO_4 (spray)	Few	Hoed (2) $NaClO_3$(2) (spray)	0	Alfalfa fair.
92	Atlacide (2) 2 lbs.	Light	Atlacide (spray) (2)	Few	Hoed (3) $NaClO_3$ (spray)	35 seedlings	Alfalfa fair. One-fourth plot bare.

TABLE 4. DETAILS OF TREATMENTS WITH DRY ATLACIDE AND SUBSEQUENT INFESTATION WITH EUROPEAN BINDWEED—Continued.

Plot no.	1930	1931		1932		1933	Remarks
	Treatment	Infestation	Treatment	Infestation	Treatment	Infestation	
99	Atlacide 2 lbs.	Light	Atlacide (spray) (2)	Few	Hoed (3) $NaClO_3$(2) (spray)	4 seedlings	Alfalfa poor.
113	Atlacide 3½ lbs.	Few	Atlacide (spray) C. K. (spray)	Few	Hoed (2) $NaClO_3$ (spray)	0	Alfalfa good.
116	Atlacide 3½ lbs.	Light	Hoed (2) $NaClO_3$ (spray)	Few	Hoed $NaClO_3$(2) (spray)	0	Alfalfa poor.
121	Atlacide 2½ lbs.	Light	Atlacide (spray) (2)	Few	Hoed (2) $NaClO_3$(2) (spray)	9 seedlings	Alfalfa poor.
	1931	1932		1933		1934	
236*	Atlacide 2 lbs.	Few	Hoed Atlacide (spray) (2)	Many seedlings	Hoed Alfalfa	0	Alfalfa fair.
237*	Atlacide 2 lbs.	Few	Hoed (2) Atlacide (spray) (2)	Many seedlings	Hoed Alfalfa	3	Alfalfa fair.

*"Light" infestation.

of Atlacide (plot 19) were no more effective than a smaller amount (plot 20). It is apparent that ⅝ to 1 pound to the square rod is too small an amount to use. Where 3½ pounds per square rod were used (plots 113, 116) the results could be considered satisfactory. The two plots (236, 237) each treated with 2 pounds of Atlacide on Oct. 17, 1932, had less than 25 plants per square rod the next year. Complete eradication was made in 2 years. The second year the individual plants were sprayed with Atlacide of a concentration of 1½ pounds per gallon.

The results show that the greatest killing action took place in the fall treatments. It is apparent that there is no need to make two or three dry applications during a season as one application suffices (plots 19, 20, 113, 236, 237). This of course cuts down the amount of labor required.

The alfalfa seedings made in 1933 were rather poor. In all probability the dry Atlacide has a greater residual effect than the spray.

POTASSIUM CHLORATE

Sodium chlorate as a herbicide has the disadvantage that it adds to the soil the sodium ion which, of course, is not necessary for plant growth. Potassium chlorate should then be preferable, since potassium is not always present in soils in sufficient amounts to produce maximum growth and is an element which plants need in their general metabolism. It is of course recognized that potassium chlorate is less soluble than sodium chlorate. A number of tests were made in 1932 to determine the possibility of using potassium chlorate as a herbicide. Data are given in table 5.

Plots 270 and 274 were given three treatments each of potassium chlorate at the rate of 3 pounds per square rod. These applications, made in July, August and October, 1932, reduced the number of European bindweed from "heavy" to "few" by 1934, even though one plot was "heavy" and the other "scattered" the previous year.

Plots 271, 375, 376, given two treatments of 1 pound of potassium chlorate, had bindweed infestation the next year ranging from "heavy" to "scattered." The bindweed in the plots receiving 2 pounds (272, 359, 360, 363, 364, 369, 371) showed "light" to "few." In the plots (365, 366, 367, 379, 380) getting 3 pounds of potassium chlorate in two spray applications, three of the five plots had only "few" plants present.

The barley seeded in the spring of 1933 became brown and died shortly after appearing above ground. The soy-

beans in 1934 and 1935 showed the effect of residual chlorate even before the cotyledons appeared above ground. The cotyledons were brown in color, somewhat deformed and failed to grow. In a short time all soybean plants were dead. The cane seeded in 1934 grew satisfactorily, while the sweet clover did not show any effect from the chlorate treatments in 1932 and 1933. In 1935 the alfalfa seeded in the various plots (table 5) was generally poor. Whether this was due to the potassium chlorate or the sodium chlorate cannot be definitely stated. Sweet clover appeared to be extremely tolerant to residual chlorate in the soil while soybeans were extremely sensitive.

As both potassium chlorate and sodium chlorate plots were established in 1932 in growing corn, the yield of dry corn should tell whether the one compound was more toxic than the other. Twenty-two of the potassium chlorate 1-square-rod plots had an average yield of 10.7 pounds; 14 of the sodium chlorate plots produced 14 pounds, while the plots receiving the usual cultivation given growing corn had an average of 18.7 pounds. Potassium chlorate apparently was slightly more toxic to corn than sodium chlorate.

Table 5 shows that potassium chlorate may be used in the same way as sodium chlorate. The amount needed for effective results in killing the European bindweed is at least 3 pounds to the square rod or about the same as is needed with sodium chlorate. As potassium chlorate is less soluble in an aqueous solution and usually costs more than sodium chlorate, there is no practical reason for the substitution of potassium chlorate for sodium chlorate in the eradication of the European bindweed.

AMMONIUM THIOCYANATE

Harvey (22) in 1931 recommended ammonium thiocyanate as a herbicide for the eradication of perennial weeds. Ammonium thiocyanate has the two-fold property of acting first as a herbicide and later as a fertilizer. Aston, Bruce and Thompson (1) have obtained favorable results from using this herbicide in fighting ragwort (*Senecio jacobea* L.). Bakke (9) stated that heavy applications of ammonium thiocyanate may be of value in eradicating leafy spurge. Ammonium thiocyanate as a herbicide for the European bindweed was tested in 1931 and 1932 at Hawarden, Iowa. The data are given in table 6.

TABLE 5. TREATMENTS WITH POTASSIUM CHLORATE AND SUBSEQUENT INFESTATION WITH EUROPEAN BINDWEED.

Plot no.	1932	1933		1934		1935	Remarks
	Treatment	Infestation	Treatment	Infestation	Treatment	Infestation	
270	$KClO_3$(3)	Heavy	Cultivated (2)	7	Alfalfa	0	Alfalfa good.
271	$KClO_3$(2)	Heavy	Cultivated (2)	15	Alfalfa	7	Alfalfa good.
272	$KClO_3$(2)	Light	Cultivated (2)	Few	Sweet clover	Few	Sweet clover good, 1935.
273	No treatment	Heavy	Cultivated (2)	Heavy	Sweet clover	Light	Sweet clover good, 1935.
274	$KClO_3$(3)	Scattered	Cultivated (2)	Few	Sweet clover	Few	Sweet clover good, 1935.
359*	$KClO_3$(2)	Scattered	Barley $NaClO_3$	Few	Cane Alfalfa	2	Alfalfa poor, 1935.
360*	$KClO_3$(2)	Scattered	Barley $NaClO_3$	Scattered	Cane Alfalfa	2	Alfalfa poor, 1935.
363	$KClO_3$(2)	Few	Barley $NaClO_3$(2)	Few	Soybeans Alfalfa	1	Soybeans poor, alfalfa good, 1935.
364	$KClO_3$(2)	Scattered	Barley $NaClO_3$(2)	Scattered	Soybeans Alfalfa	1	Alfalfa fair, 1935.
365	$KClO_3$(2)	Scattered	Barley $NaClO_3$(2)	Few	Soybeans Alfalfa	5	Soybeans, alfalfa poor, 1935.
366	$KClO_3$(2)	Few	Barley $KClO_3$ $NaClO_3$	7	Soybeans Alfalfa	2	Soybeans, alfalfa poor, 1935.
367	$KClO_3$(2)	Light	Barley $NaClO_3$(2)	Few	Soybeans Alfalfa	3	Alfalfa poor.

TABLE 5. TREATMENTS WITH POTASSIUM CHLORATE AND FOLLOWING INFESTATION WITH EUROPEAN BINDWEED —Continued.

Plot no.	1932	1933		1934		1935	Remarks
	Treatment	Infestation	Treatment	Infestation	Treatment	Infestation	
368*	$KClO_3$(2)	Few	Barley $NaClO_3$(2)	Few	Soybeans Alfalfa	3	Soybeans poor, alfalfa poor.
369	$KClO_3$(2)	Few	Barley $NaClO_3$(2)	Few	Soybeans Alfalfa	3	Soybeans poor, alfalfa poor.
370	No treatment	Heavy	Barley	Heavy	Soybeans Alfalfa	Light	Soybeans poor, alfalfa fair.
371	$KClO_3$(2)	Light	Barley $NaClO_3$(2)	Scattered	Soybeans Alfalfa	1	Soybeans poor, alfalfa poor.
372*	$KClO_3$(2)	Few	Barley $NaClO_3$(2)	Few	Soybeans Alfalfa	8	Soybeans poor, alfalfa fair.
373*	$KClO_3$(2)	0	Barley $KClO_3$ $NaClO_3$	1	Soybeans Alfalfa	1	Soybeans poor, alfalfa poor.
374*	$KClO_3$(2)	Few	Barley $NaClO_3$(2)	2	Soybeans Alfalfa	1	Soybeans dead, alfalfa fair.
375	$KClO_3$(2)	Scattered	Barley $NaClO_3$(2)	3	Soybeans Alfalfa	1	Soybeans dead, alfalfa poor.
376	$KClO_3$(2)	Scattered	Barley $NaClO_3$(2)	2	Soybeans Alfalfa	2	Soybeans dead, plot bare.
377	$KClO_3$(2)	Scattered	Barley $NaClO_3$(2)	3	Soybeans Alfalfa	2	Plot bare.
378*	$KClO_3$(2)	Few	Barley $NaClO_3$(2)	3	Soybeans Alfalfa	2	Plot bare.
379*	$KClO_3$(2)	Few	Barley $NaClO_3$(2)	3	Soybeans Alfalfa	2	Plot bare.
380*	$KClO_3$(2)	Few	Barley $NaClO_3$(2)	3	Soybeans Alfalfa	4	Plot bare.

*"Light" infestation.

TABLE 6. TREATMENTS WITH AMMONIUM THIOCYANATE AND SUBSEQUENT INFESTATION WITH EUROPEAN BINDWEED.

Plot no.	1931	1932		1933		1934	Remarks
	Treatment	Infestation	Treatment	Infestation	Treatment	Infestation	
226	NH_4CNS 1 lb.	Light	NH_4CNS(2) 4 lbs.	Light	Barley Alfalfa	Light	Alfalfa good. No bindweeds, 10-9-35.
227	NH_4CNS 1 lb.	Light	Hoed NH_4CNS(3) 3 lbs.	Light	Barley Alfalfa	Light	Alfalfa good. 3 bindweeds, 10-9-35.
228	NH_4CNS(2) 2 lbs.	Light	Hoed NH_4CNS(3) 6 lbs.	Light	Barley Alfalfa	Light	Alfalfa good. Corn striped, 1932. No bindweeds, 1935.
229	NH_4CNS 2 lbs.	Light	Hoed NH_4CNS(3) 6 lbs.	Light	Barley Alfalfa	Light	Alfalfa good. 11 bindweeds, 1935.
230	NH_4CNS 2½ lbs.	Light	Hoed NH_4CNS(3) 7 lbs.	Light	Barley Alfalfa	Light	Alfalfa good. 4 bindweeds, 5-1-35.
231	NH_4CNS(2) 4½ lbs.	Light	Hoed NH_4CNS(2) 5 lbs.	Light	Barley Alfalfa	Light	Alfalfa good.
233	NH_4CNS 3½ lbs.	Heavy	Hoed NH_4CNS(2) 6 lbs.	Light	Barley Alfalfa	Light	Alfalfa good.
234	NH_4CNS 3½ lbs.	Heavy	Hoed NH_4CNS(2) 6 lbs.	Light	Barley Alfalfa	Light	Alfalfa good.
235	NH_4CNS 4 lbs.	Light	Hoed NH_4CNS(2) 8 lbs.	Light	Barley Alfalfa	Light	Alfalfa good.

TABLE 6. TREATMENTS WITH AMMONIUM THIOCYANATE AND SUBSEQUENT INFESTATION WITH EUROPEAN BINDWEED—Continued.

	1932	1933		1934		1935	
264*	NH_4CNS(2) 4 lbs.	Light	Cultivated (2)	0	Fallowed alfalfa	0	Alfalfa good.
265	NH_4CNS(3) 12 lbs.	Few	Cultivated (2)	5	Fallowed alfalfa	0	Alfalfa good.
266	NH_4CNS(2) 6 lbs.	Heavy	Cultivated (2)	8	Fallowed alfalfa	0	Alfalfa good.
267	NH_4CNS(2) 6 lbs.	Heavy	Cultivated (2)	12	Fallowed alfalfa	0	Alfalfa good.
268	NH_4CNS 10 lb.	Heavy	Cultivated (2)	4	Fallowed alfalfa	0	Alfalfa good.
269	NH_4CNS 10 lbs.	Heavy	Cultivated (2)	3	Alfalfa	0	Alfalfa good.
315	NH_4CNS(2) 4 lbs.	Heavy	Cultivated (2)	3	Buckwheat $NaClO_3$		Seeded to sudan grass. 2 bindweeds, plowed, 1935.
316	NH_4CNS+HCHO(3) 6 lbs.	Heavy	Cultivated (2)	3	Buckwheat $NaClO_3$		Seeded to sudan grass, 1935. 2 bindweeds, plowed.
317	NH_4CNS+HCHO(2) 4 lbs.	Heavy	Cultivated (2)	Few	Buckwheat $NaClO_3$		Seeded to sudan grass, 1935. 5 bindweeds, plowed.
318	NH_4CNS+HCHO(2) 4 lbs.	Heavy	Cultivated (2)	Few	Buckwheat $NaClO_3$		Seeded to sudan grass, 1935. 16 bindweeds, plowed.
319	NH_4CNS+HCHO 4 lbs.	Heavy	Cultivated (2)	6	Buckwheat $NaClO_3$		Seeded to sudan grass, 1935. 9 bindweeds, plowed.
390	NH_4CNS+HCHO 6 lbs.	Light	Cultivated (2)	8	Buckwheat $NaClO_3$		4 bindweeds.

*"Light" infestation of European bindweed.

A study of the nine 1-square-rod plots harboring a heavy infestation of European bindweed and treated with ammonium thiocyanate in September, 1931, in amounts ranging from 1 to 4½ pounds, showed unsatisfactory results. With subsequent treatments in 1932 (3 to 8 pounds ammonium thiocyanate), the bindweed infestation was still "light." It was noted that the plots given two treatments in 1932 (226, 231, 233, 234, 235) and the plots given three treatments in 1932 (227, 228, 229, 230) still had a "light" infestation of bindweed in 1934.

In the 1932 plots where the first treatment was made in July and the amount of ammonium thiocyanate varied from 4 to 10 pounds, the bindweed infestation with two cultivations was reduced to "few" (plots 317, 318) or less (plots 264, 269, 315, 320) in 1934. The addition of 1 ounce of formaldehyde to each gallon of solution did not produce increased action. Four pounds of ammonium thiocyanate applied at one time (plot 319) gave practically as good results as when two treatments (plots 264, 315, 317, 318) were made. Plot 316 which received in the aggregate 6 pounds in three applications had three bindweeds in 1934, while plots 266 and 267 with two applications (6 pounds) had all bindweeds exterminated. The better and more consistent results in 1932 may be attributed to the fact that the first application of ammonium thiocyanate was made in July during active growth of bindweed, while the 1931 applications were made in September.

The barley seeded in the spring of 1933 attained a healthy vigorous growth and did not show any deleterious effect from the ammonium thiocyanate. The same was true of the alfalfa. In 1935 the alfalfa was much more vigorous than on the untreated areas.

The point made by Harvey (22) that ammonium thiocyanate is toxic at time of application and later acts as a fertilizer may be noted from the corn yields on the plots first treated in 1932. At that time 12 1-square-rod plots produced on the average 5.3 pounds of dry corn while in 1933 the average yield was 35.3 pounds. Attention has been called in table 6 to the striped leaves in plot 228.

From the data of 1931, and particularly that of 1932, it is evident that ammonium thiocyanate may be used as a herbicide. The use of ammonium thiocyanate deserves further attention than has been given. If 4 to 5 pounds of ammonium thiocyanate per square rod can eliminate a heavy infestation of European bindweed, it could at least partially replace the chlorates.

TABLE 7. TREATMENTS WITH SULFURIC ACID AND SUBSEQUENT INFESTATION WITH EUROPEAN BINDWEED.

Plot no.	1930	1931		1932		1933	Remarks
	Treatment	Infestation	Treatment	Infestation	Treatment	Infestation	
30*	H_2SO_4 $NaClO_3$	0	Hoed (3)	0		0	Alfalfa seeded, 1933. Very good.
31	H_2SO_4 $NaClO_3$	Light	Hoed $NaClO_3$(2)	0	Hoed (4) $NaClO_3$	0	Alfalfa seeded, 1933. Very good.
32	H_2SO_4 $NaClO_3$	Few	Atlacide(2) †	0	Hoed (3) $NaClO_3$	0	Alfalfa seeded, 1933. Very good.
	1931	1932		1933		1934	
151**	H_2SO_4 $NaClO_3$ (dry)	0	$NaClO_3$(2)	0	Alfalfa	0	

*"Light" infestation of European bindweed.
**"Few" European bindweed.
†Leafy spurge present.

SULFURIC ACID

Åslander (3), Brown and Streets (15), Skilbeck and Coles (41), and Ball and French (6) have shown that sulfuric acid may be used in eradicating annual weeds, through its corrosive action.

In the investigations reported in this bulletin, the use of sulfuric acid as a herbicide was not expected to eradicate bindweed completely, but it was thought that it might be used as a substitute for one of the two sodium chlorate sprays of a season, since the bindweeds recover rather slowly after being treated with sulfuric acid. The data obtained from the use of sulfuric acid are given in table 7.

Plots 30, 31 and 32 were each sprayed in July, 1930, with 1 gallon of 10 percent sulfuric acid with the result that all aerial growth was killed. In September after there was a vigorous second growth, 2½ gallons (1 pound per gallon) of a sodium chlorate solution were applied in the form of a spray. The bindweed population the following year varied from none to "light." With three hoeings (plot 30), one hoeing and two sodium chlorate (plot 31), and two Atlacide treatments (plot 32), no bindweeds were found in June, 1932. The sprayings made in 1932 were for the purpose of killing the leafy spurge.

Plot 151 had only "few" bindweeds in 1931. The plants were sprayed with a 10 percent sulfuric acid solution on July 15 and treated with dry sodium chlorate (2 pounds) on Oct. 17. The two sprayings in 1932 when no more than two plants were present at any time completed the extermination.

From the results obtained from using sulfuric acid in conjunction with sodium chlorate, it would seem as though it merits further experimental work. Sulfuric acid is cheap and may act as a fertilizer for subsequent plant growth. It has the disadvantage that it is a corrosive and must be handled carefully. These difficulties have been eliminated by using lead-lined sprayers. Certain power sprayers have provisions for carrying the acid directly to the ejector.

CREOSOTE-KEROSENE MIXTURES—C. K. (10-90)

Creosote-kerosene mixtures have been extensively used by certain railroads in destroying the weeds along their right-of-ways. A series of experiments to determine whether C. K. (10-90)—creosote 10 parts, distillate 90

parts—had any merit as a herbicide for the European bindweed, were made during the years 1930-32. The results are given in table 8.

One spraying of C. K. (10-90) with amounts ranging from 400-500 gallons per acre in 1930 did not materially reduce the European bindweed. One C. K. and one sodium chlorate, one Atlacide or one sulfuric acid application (plots 27, 33, 38, 39, 63, 65, 70, 72, 73) did not give satisfactory results. It was necessary to make further herbicidal and cultural treatments in 1931 and 1932.

Four of the six plots (29, 64, 67, 68, 69, 71) given two C. K. treatments varying in amount from 600 to 1,000 gallons per acre were still heavily infested with bindweed the next year. In order completely to exterminate the weeds, sodium chlorate or Atlacide was used.

Plots 184, 185, 188, 191, given two applications of C. K. in 1931 and in 1932, showed a marked reduction in the number of the bindweeds. By cultivation throughout the greater part of the growing season of 1934 and the seeding of alfalfa in August of that year, the bindweeds were destroyed (plots 184, 185). Plot 186 with one C. K. treatment and one sodium chlorate treatment in 1931 was given two sodium chlorate applications in 1932 before all bindweeds were killed. Where sulfur or sulfuric acid was used in combination with C. K. (plots 187, 189, 190), a large number of seedlings appeared in 1933. This was probably due to the corrosive action on the seed coats of otherwise impermeable seed.

Two of the four C. K. treatments in 1932 (plots 259-262), aggregating 800-1,500 gallons per acre, with cultivation in 1933 and 1934, along with the seeding of alfalfa in August, 1934, practically exterminated all the bindweed.

It would seem as if the creosote mixture (C. K.) is not an effective herbicide for the European bindweed. By using large amounts on two consecutive years or by using large amounts the first year and subsequent cultivation at frequent intervals, the bindweeds may be destroyed.

SODIUM CHLORIDE

Sodium chloride has often been used to exterminate plants. Its action is due to the presence of a solution of greater osmotic pressure than that of the plant tissues. Call and Getty (16) have recommended salt for the eradication of the European bindweed. At Fort Hays, Kansas, where they used 20 tons per acre in 1913, no other vegetation except Russian thistle was present in 1923. Kies-

TABLE 8. TREATMENTS WITH C. K. (10-90) AND SUBSEQUENT INFESTATION WITH EUROPEAN BINDWEED.

Plot no.	1930	1931		1932		1933	Remarks
	Treatment	Infestation	Treatment	Infestation	Treatment	Infestation	
27	CK-400 gals. per acre $NaClO_3$	Medium	$NaClO_3$(2)	5	Hoed $NaClO_3$(2)	0	Alfalfa seeded, 1933, good.
28	CK-500 gals. per acre	Heavy	$NaClO_3$(3)	5	Hoed (2) $NaClO_3$	0	Alfalfa seeded, 1933, good.
29	CK-400 (2)	Light	Hoed (2)	0	Hoed (3)	0	Alfalfa seeded, 1933, good.
33	CK-400 $NaClO_3$ (dry)	Few	Atlacide (2)	2	Hoed (3) $NaClO_3$(2)	0	Alfalfa spotted.
38	CK-200 $NaClO_3$ (dry)	Scattered	Hoed (2)	Few	Hoed (3) $NaClO_3$	7 seedlings	Alfalfa good.
39	CK-250 $NaClO_3$	Heavy	$NaClO_3$(2)	Few	Hoed (3) $NaClO_3$(2)	1 seedling	Alfalfa poor.
40	CK-200 CK-400	Few	Hoed (4)	1	Hoed (3) $NaClO_3$	0	Alfalfa very good.
63	CK-400	Light	$NaClO_3$(2)	Scattered	Hoed (3) $NaClO_3$(2)	0	Alfalfa short.
64	CK-400 (2)	Heavy	$NaClO_3$	Light	Hoed (3) $NaClO_3$(2)	0	Alfalfa light.
65	CK-400 $NaClO_3$	5	H_2SO_4	Few	Hoed (3) $NaClO_3$(2)	0	Alfalfa very good, 1934.
66	CK-500	Light	Atlacide (2)	Few	Hoed (3) $NaClO_3$(2)	1	Alfalfa very good.
67	CK-500 (2)	Light	$NaClO_3$(2)	3	Hoed (3) $NaClO_3$(2)	6	Alfalfa poor.

TABLE 8. TREATMENTS WITH C. K. (10-90) and SUBSEQUENT INFESTATION WITH EUROPEAN BINDWEED—Continued.

Plot no.	1930	1931		1932		1933	Remarks
	Treatment	Infestation	Treatment	Infestation	Treatment	Infestation	
68	CK-300 (2)	Heavy	$NaClO_3$(2)	Few	Hoed (3) $NaClO_3$(2)	2 seedlings	Alfalfa light, spotted.
69*	CK-300 (2)	Heavy	Atlacide (2)	Few	Hoed $NaClO_3$(2)	86 bindweed seedlings	Alfalfa light.
70*	CK-500 Atlacide	Heavy	Atlacide (2)	Few	Hoed (2) $NaClO_3$(2)	3	Alfalfa light.
71	CK-250 CK-500	Heavy	Hoed Atlacide	Few	Hoed (3) $NaClO_3$(2)	4	Alfalfa good.
72	CK-250 $NaClO_3$	Light	$NaClO_3$(2)	Few	Hoed (3) $NaClO_3$(2)	1	Alfalfa poor.
73*	CK-250 Atlacide	Light	H_2SO_4 Atlacide	1	Hoed (3) $NaClO_3$(2)	0	Alfalfa good.
100*	CK-400	Light	$NaClO_3$(2)	Few	$NaClO_3$(2)	1	Alfalfa good.
107	CK-500	Heavy	Atlacide (2)	Few	Hoed (2) $NaClO_3$(2)	5	Alfalfa good—one bare spot, 4x10 ft.
118	CK-400	Heavy	H_2SO_4 $NaClO_3$	3	Hoed (2) $NaClO_3$(2)	4	Alfalfa fair.
	1931	1932		1933		1934	
184	CK-400 (2)	Light	Hoed CK-400 (3)	Light	Hoed	16	Fallowed, alfalfa, 1934.
185	CK-400 (2)	Light	Hoed CK-400 (3)	Light	Hoed	54	Fallowed, alfalfa, 1934.
186	CK-400 $NaClO_3$	Few	Hoed $NaClO_3$(2)	33 seedlings	Barley Alfalfa	1	Barley very poor, 1933, alfalfa good.
187	CK-400 H_2SO_4	Light	Hoed $NaClO_3$(2)	507 seedlings	Barley Alfalfa	0	Barley very poor, 1933, alfalfa good.
188	CK-500 (2)	Light	Hoed CK-400 (2)	Light	Barley Alfalfa	Light	Barley fair, 1933, light alfalfa, no bindweed in 1934.
189	CK-500 Sulfur (2 lbs.)	Light	Hoed $NaClO_3$(2)	Numerous seedlings	Barley Alfalfa	0	Barley poor in 1933, alfalfa fairly good.

TABLE 8. TREATMENTS WITH C. K. (10-90) and SUBSEQUENT INFESTATION WITH EUROPEAN BINDWEED—Continued.

Plot no.	1931	1932		1933		1934	Remarks
	Treatment	Infestation	Treatment	Infestation	Treatment	Infestation	
190	CK-500 Sulfur (2 lbs.)	Light	$NaClO_3$(3)	Numerous seedlings	Barley Alfalfa	1	Barley poor in 1933, alfalfa fairly good.
191	CK-500 (2)	Light	CK-400 (2)	44 seedlings	Barley Alfalfa	6	Barley very poor in 1933, alfalfa good. Bindweeds removed with hoe.
	1932	1933		1934		1935	
259*	CK-400 (2)	Few	Hoed Cultivated (2)	0	Fallowed Alfalfa	0	Alfalfa good.
260	CK-400 (3)	Medium	Hoed Cultivated (2)	6	Fallowed Alfalfa	0	Alfalfa good.
261	CK-500 (2)	Medium	Hoed Cultivated (2)	Few	Fallowed Alfalfa	6	Alfalfa good.
262	CK-500 (3)	Medium	Hoed Cultivated (2)	Few	Fallowed Alfalfa	6	Alfalfa good.
263	No treatment	Heavy	Cultivated (3)	Scattered	Fallowed Alfalfa	3	Alfalfa good.

*"Light" infestation of European bindweed.

selbach, Petersen and Burr (29) added salt at the rate of 1 pound per square foot to a patch of European bindweed at Lincoln, Nebraska. At the end of 6 years, the ground was still bare.

A series of 1-square-rod plots was treated with sodium chloride in 1931 and 1932. The amount added in 1931 was small, the purpose being to determine whether small amounts of salt would assist in the eradication through subsequent use of sodium chlorate or alfalfa. The data are given in table 9.

Sodium chloride, in order to eradicate the European bindweed, must be used in large quantities. Seventy-five pounds to the square rod in 1932 (plot 298) with two cultivations in 1933 reduced the bindweed infestation from "heavy" to "light." The smaller amounts used in 1931 and in 1932 did not have any appreciable effect. Two sodium chlorate sprayings on plot 221 along with cultivation in 1933 and 1934 exterminated all the bindweeds. The alfalfa seeded in 1934 was very poor in all cases and so did not offer competition to the bindweed.

SULFUR

Since sulfur added to a soil has an action similar to sulfuric acid, it seemed logical that sulfur scattered over an area infested with bindweed would make subsequent sodium chlorate treatments more effective than where sulfur was not used. Table 10 gives the results from using sulfur.

In all the plots treated with sulfur in the fall of 1931, there were numerous bindweed seedlings in the spring of 1933. When neither sulfur nor sulfuric acid has been used, the number of seedlings appearing subsequently has been comparatively small. The addition of sulfur to ground which has been infested with bindweed for a long time may be of considerable importance in hastening the germination of dormant seed. Hegi (23) has called attention to the fact that the seeds of the European bindweed may remain dormant for 22 years. If the bindweed seeds can be made to germinate more quickly through the addition of a small amount of sulfur, considerable time and labor may be saved in cleaning up an infested area.

Little is to be gained by applying sulfur one year and following this treatment with sodium chlorate the next year. Fully as good results have been obtained by use of sodium chlorate without preliminary treatment with sulfur.

TABLE 9. TREATMENTS WITH SODIUM CHLORIDE AND SUBSEQUENT INFESTATION WITH EUROPEAN BINDWEED.

Plot no.	1931	1932		1933		1934	Remarks
	Treatment	Infestation	Treatment	Infestation	Treatment	Infestation	
194	NaCl (35%) solution	Medium	NaCl (35%) (3)	Medium	Barley Manure	Heavy	Barley fair in 1935. "Few" bindweeds, 1935.
195	NaCl (35%) solution	Light	Sweet clover, rye	Medium		Heavy	
221	NaCl (dry) 2½ lbs.	Medium	Hoed $NaClO_3$(2)	1	Cultivated	Scattered	Alfalfa seeded, 1934. No bindweed, 1935.
223	NaCl (dry) 2 lbs.	Medium	NaCl (2) (dry) 3 lbs.-4 lbs.	Medium	Cultivated	Light	Alfalfa seeded, 1934. Four bindweeds, 1935.
225	NaCl (dry) 1 lb.	Light	NaCl (3) 1 lb.	Heavy	Hoed	Light	Fallowed, alfalfa. No bindweed, 1935.
	1932	1933		1934		1935	
295	NaCl(3) 30 lbs.	Heavy	Cultivated	Heavy	Sudan grass Alfalfa	Light	Alfalfa poor.
296	NaCl(2) 20 lbs.	Heavy	Cultivated (2)	Heavy	Sudan grass Alfalfa	Scattered	Alfalfa poor.
297	No treatment	Heavy	Cultivated (2)	Heavy	Sudan grass Alfalfa	Light	Alfalfa poor.
298	NaCl(3) 75 lbs.	Light	Cultivated (2)	29	Sudan grass Alfalfa	Light	Alfalfa poor.
299	NaCl(2) 50 lbs.	Light	Cultivated (2)	Heavy	Sudan grass Alfalfa	Light	Alfalfa poor.

TABLE 10. TREATMENTS WITH SULFUR AND SUBSEQUENT INFESTATION WITH EUROPEAN BINDWEED.

Plot no.	1931	1932		1933		1934	Remarks
	Treatment	Infestation	Treatment	Infestation	Treatment	Infestation	
214	Sulfur 10 lbs.	Light	Hoed $NaClO_3$(3)	Numerous seedlings	Barley Alfalfa	Light	Barley poor in 1933. No bindweed, 1935.
215	Sulfur 10 lbs.	Light	Hoed $NaClO_3$(3)	Numerous seedlings	Barley Alfalfa	Light	Barley poor, alfalfa poor, 1933.
216	Sulfur 5 lbs.	Light	$NaClO_3$(3)	Numerous seedlings	Barley Alfalfa	Few seedlings	No bindweed, 1935.
217	Sulfur 2 lbs. NaCl (35%)	Heavy	Hoed $NaClO_3$(3)	Numerous seedlings	Hoed	Few seedlings	Fallowed, seeded to alfalfa, 1934.
218	Sulfur 5 lbs.	Heavy	Hoed $NaClO_3$(2)	Numerous seedlings	Hoed	Light	Fallowed, seeded to alfalfa, 1934.
219	Sulfur 5 lbs.	Light	Hoed $NaClO_3$(2)	Many seedlings	Hoed	Light	Fallowed, alfalfa, 1934.
220	Sulfur 2½ lbs.	Light	Hoed $NaClO_3$(2)	Few seedlings	Cultivated	Light	Fallowed, alfalfa, 1934.
222	Sulfur 2 lbs.	Light	Hoed $NaClO_3$(2)	Numerous seedlings	Cultivated	0	Fallowed, alfalfa, 1934.
224	Sulfur 1 lb.	Light	Hoed $NaClO_3$(2)	Numerous seedlings	Hoed	Few	Fallowed, alfalfa, 1934.

"CHLORON"

"Chloron," a chemical weed killer (probably largely chlorinated lime) advertised a great deal in 1931 and 1932 as an effective herbicide, was tried on the bindweeds of plots 300-306. The results are given in table 11.

The six plots sprayed with "chloron" in amounts varying from 2 to 7½ pounds in 1932, followed by two cultivations, had subsequent infestations of bindweed ranging from "light" to "scattered." With sudan grass and alfalfa in 1934, the number of bindweeds was further reduced to two up to "scattered." It was noticed that plot 304 which did not have any "chloron" had "scattered" plants in 1935.

OTHER CHEMICALS

Bolley (12) used iron sulfate in the eradication of mustard in grain fields in North Dakota, and Munn (34) got good results in eradicating dandelions from lawns by spraying them with iron sulfate (1½ pounds per gallon of water) five times during a season at the rate of 4 pounds per 1,000 square feet. Long (31) has recommended for dandelion eradication a mixture of 100 pounds ammonium sulfate, 100 pounds of iron sulfate and 400 pounds of dry soil and sand per acre. The mixture is applied monthly between April and September.

In 1930, as a preliminary test, one plot was treated with iron sulfate, one with hypochloride of lime, one with borax and one with zinc sulphate. The data are given in table 12.

Plot 34, with a heavy infestation of bindweed, was treated with iron sulfate (2 pounds per gallon) on July 4 and again on Sept. 16, 1930. On April 29 of the following year, the ground was covered with bindweeds.

Plot 35, heavily infested with bindweed, was given a saturated solution of hypochloride of lime $Ca(ClO)_2$ in 1931. There was no reduction in the number of bindweeds.

Borax is known to be toxic to plants. Spraying the heavy growth of bindweeds with a solution of borax (½ pound per gallon) on July 4, 1930, did not produce any effect.

Zinc sulfate, in a concentration of 2 pounds to 5 gallons of water, did not have any effect upon the bindweeds.

The results from iron sulfate, hypochloride of lime, borax and zinc sulfate did not seem to warrant further attention to these materials.

Considerable success has been reported from using arsenic compounds. Gray (21) and Crafts (18) have found that arsenical sprays produce good results upon the

TABLE 11. TREATMENTS WITH "CHLORON" AND SUBSEQUENT INFESTATION WITH EUROPEAN BINDWEED.

Plot no.	1932	1933		1934		1935	Remarks
	Treatment	Infestation	Treatment	Infestation	Treatment	Infestation	
300	Chloron(2) 2 lbs.	Heavy	Cultivated (2)	Light	Sudan grass Alfalfa	2	Alfalfa poor.
301	Chloron(3) 3 lbs.	Heavy	Cultivated (2)	Light	Sudan grass Alfalfa	4	Alfalfa poor.
302	Chloron(2) 4 lbs.	Scattered	Cultivated (2)	Few	Sudan grass Alfalfa	8	Alfalfa in west half of plot fair.
303	Chloron(3) 6 lbs.	Heavy	Cultivated (2)	Scattered	Sudan grass Alfalfa	7	Alfalfa fair, no bindweed, Oct., 1935.
304	No treatment	Heavy	Cultivated (2)	Heavy	Sudan grass Alfalfa	Scattered	Alfalfa fair.
305	Chloron(2) 5 lbs.	Heavy	Cultivated (2)	Light	Sudan grass Alfalfa	Scattered	Alfalfa fair.
306	Chloron(3) 7½ lbs.	Heavy	Cultivated (2)	Light	Sudan grass Alfalfa	Scattered	Alfalfa fair.

TABLE 12. TREATMENT WITH IRON SULFATE, HYPOCHLORIDE OF LIME, BORAX AND ZINC SULFATE AND SUBSEQUENT INFESTATION WITH EUROPEAN BINDWEED.

Plot no.	1930	1931		1932		1933	Remarks
	Treatment	Infestation	Treatment	Infestation	Treatment	Infestation	
34	$FeSO_4$(2)	Heavy	$NaClO_3$(3)	11	Hoed (2) $NaClO_3$(2)	0	Alfalfa seeded, August, 1933. No bindweed.
35	$Ca(ClO)_2$	Heavy	$NaClO_3$ Atlacide	Few	Hoed (3) $NaClO_3$(2)	1 seedling	Alfalfa seeded, 1933. Good. No bindweed, 1934.
36	Borax	Heavy	Atlacide (2)	Few	Hoed (3) $NaClO_3$(2)	18 seedlings	Alfalfa seeded, 1933. Good. No bindweed, 1934.
37	$ZnSO_4$	Heavy	$NaClO_3$(2)	Few	Hoed (3) $NaClO_3$(2)	29 seedlings	Alfalfa seeded, 1933. Good. No bindweed, 1934.

European bindweed. Recently Aston, Bruce and Thompson (2) have used sodium bisulphite ($NaHSO_3$), potassium bisulphite ($KHSO_3$) and sodium ammonium bisulphite [$NaNH_4(HSO_3)_2$], and found that a 10 percent solution of ammonium thiocyanate, a 5 percent solution of sodium chlorate and a 15 percent solution of sodium bisulphite are approximately equally efficient in killing the ragwort. Rogers (37) has recommended the use of carbon disulphide for the eradication of Canada thistle and Russian knapweed. Ball, Crafts, Madson and Robbins (7) have called attention to the fact that the manufacturers of carbon disulphide have a special subsoiler equipped so as to distribute the substance into the soil. Bermuda grass and nut grass have been successfully exterminated by sprinkling the soil with carbon disulphide and immediately covering it with a wet canvas. The cost, however, is excessive, being $200 to $250 per acre.

FERTILIZER (KAINITE)

It is generally known that fertilizers may be applied in large enough quantities to be toxic to the plants grown on the area. Whether or not large quantities of commercial fertilizer would eradicate the European bindweed was tested in 1932. "Kainite" (potassium chlor-sulfate) available at the time was used. The data are given in table 13. Kainite is seen to be of little importance in the eradication of the European bindweed.

CULTURAL PRACTICES

REDUCTION IN CROP YIELDS FROM BINDWEED INFESTATION

Gates and Cox (20) have stated that weeds make the cultivation of corn necessary. Hunt (24) has demonstrated that weeds exhaust moisture from the soil. To determine the effect of bindweed upon the growth of corn, daily growth measurements were made of three stalks growing in each of two hills in plot 1 where the ground was kept clean throughout the season and in two hills on plot 3 heavily infested with bindweed. Both plots had received two cultivations. Measurements were taken daily at the same time of the day from July 1 until Aug. 4, at which time the corn had completed its growth. Data submitted in table 14 are the averages in each case of the six plants used.

On examination of the height of corn stalks in the corn field given three cultivations, directly adjoining the 1930 plots and used as a control, it was found that the stalks were about 8 1/3 feet tall where the corn was free of

TABLE 13. TREATMENTS WITH THE COMMERCIAL FERTILIZER "KAINITE" AND SUBSEQUENT INFESTATION WITH EUROPEAN BINDWEED.

Plot no.	1932	1933		1934		1935	Remarks
	Treatment	Infestation	Treatment	Infestation	Treatment	Infestation	
307	Kainite (2) 10 lbs.	Heavy	Cultivated (2)	Heavy	Sudan grass Alfalfa	Scattered	Alfafa fair.
308	Kainite (2) 10 lbs.	Heavy	Cultivated (2)	Heavy	Sudan grass Alfalfa	Scattered	Alfafa fair.
309	Kainite (2) 20 lbs.	Heavy	Cultivated (2)	Light	Sudan grass Alfalfa	Few	Alfafa fair.
310	Kainite (2) 20 lbs.	Heavy	Cultivated (2)	Heavy	Sudan grass Alfalfa	Light	Alfafa fair.
311	Kainite (2) 30 lbs.	Medium	Cultivated (2)	Heavy	Sudan grass Alfalfa	Light	
312	Kainite (2) 30 lbs.	Light	Cultivated (2)	Scattered	Buckwheat $NaClO_3$	11	Seeded to sudan grass, 1935, plowed.
313	Kainite (2) 40 lbs.	Heavy	Cultivated (2)	Few	Buckwheat $NaClO_3$	2	Seeded to sudan grass, 1935, plowed.
314	Kainite (2) 40 lbs.	Heavy	Cultivated (2)	Few	Buckwheat $NaClO_3$	36	Seeded to sudan grass, 1935, plowed.

TABLE 14. DAILY GROWTH IN INCHES OF CORN PLANTS FROM JULY 1 TO AUGUST 4, 1930.

Date	Plot 1. Kept clean by hoeing	Plot 3. No treatment
July 1	1.4	1.4
2	2.7	1.4
3	3.7	1.8
4	3.1	1.3
5	4.2	2.1
6	4.0	2.3
7	4.3	2.0
8	4.2	1.4
9	3.5	1.2
10	3.4	1.2
11	3.9	1.2
12	3.6	0.8
13	3.9	1.0
14	3.8	0.5
15	2.9	0.4
16	3.5	0.8
17	3.6	0.8
18	2.8	0.7
19	3.8	0.5
20	4.1	0.6
21	3.8	0.7
22	2.7	1.0
23	2.9	0.5
24	3.4	0.3
25	3.3	0.3
26	3.0	0.6
27	2.4	0.7
28	1.3	0.3
29	2.2	0.5
30	1.1	0.3
31	1.4	0.6
Aug. 1	1.3	0.4
2	1.2	0.5
3	0.7	0.3
Final height	8′ 4″	2′ 6″
Yield	17¼ lbs.	2.7 lbs.

weeds. Where the bindweed infestation was severe, the stalks were in many cases less than 2¼ feet in height. Measurements of growth and yield show the reduction in the crop yield due to European bindweed (fig. 8).

In order to obtain some idea of the amount of aerial growth of European bindweed, weighings of the stems and leaves of two plots were made. The bindweed on plot 48 was allowed to grow undisturbed until July 8, 1930, when the green material was cut off and weighed; on July

TABLE 15. GREEN WEIGHT OF BINDWEED AND CORN PLANTS ON TWO PLOTS IN 1930.

Plot no.	Date of collection	Green weight of bindweed	Green weight of corn plants
48	July 8 Sept. 17	57 lbs. 28¼ lbs.	18 lbs. -------
76	July 19	43 lbs.	28½ lbs.

19, the green weight on plot 76 was ascertained by weighing. The data are recorded in table 15.

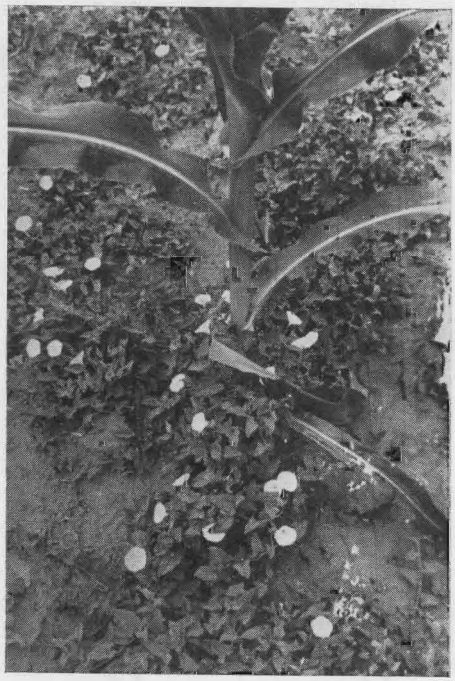

Fig. 8. Bindweed vines twine about the stalks of corn.

The green weight of the European bindweed was greater than that of the corn. From the ground of plot 76 spaded to a depth of 8 inches, 1 pound of bindweed roots was collected.

FALLOWING

Even though the European bindweed produces a heavy growth of aerial shoots in a short time, it is obvious that if cultivations are made often enough and sufficiently thorough the bindweed cannot develop. Fallowing to exterminate bindweed consists of cultivating the ground so that no aerial growth is formed or, if a small amount of growth is produced, it will be at the expense of the food reserves in the subterranean parts. It is a common practice in many sections of the country to summer fallow in order to exterminate weeds. Brenchley (13) has stated that fallowing may reduce the weed population considerably if the process can be carried on long enough to exhaust the food reserves. Åslander (5) has stated that the most important feature of summer fallowing is its effect upon perennial weeds. He has advocated the ridge fallow method, which to all appearances produces the same results as when a lister is used. He contends that fallowing makes available the soil nitrogen, especially the part contained in the roots of perennial weeds.

Cox (17) in 1909 suggested clean cultivation as an effective measure in eradicating bindweed. Biolette (11) used a special cultivator which cut the bindweed roots to a

depth of 3 inches. Thirty cuttings in one season materially reduced the bindweed population. The purpose, as stated by him, was to promote continuous new growth in order to exhaust the food reserve of the root system, and then remove this growth before it had an opportunity to replenish the food supplies. Call and Getty (16) recommended intensive cultivation, with an average of about 20 tillages during a season. A spring shovel cultivator equipped with 10-inch sweeps worked satisfactorily. From 85 to 99 percent of the bindweed was eradicated in one season. Complete eradication required about a dozen cultivations the second year.

Barnum (10) said thorough and frequent cultivation during one season killed the plant in 1 year. The interval between cultivations should not be greater than 5 days. No green leaves should be allowed to appear.

Kiesselbach, Petersen and Burr (29) have suggested clean tillage immediately after grain harvest in July and continued throughout the next year as a method for bindweed eradication. In this way only one crop is lost. A detailed history of a number of cultivations made at different frequencies is given in table 16.

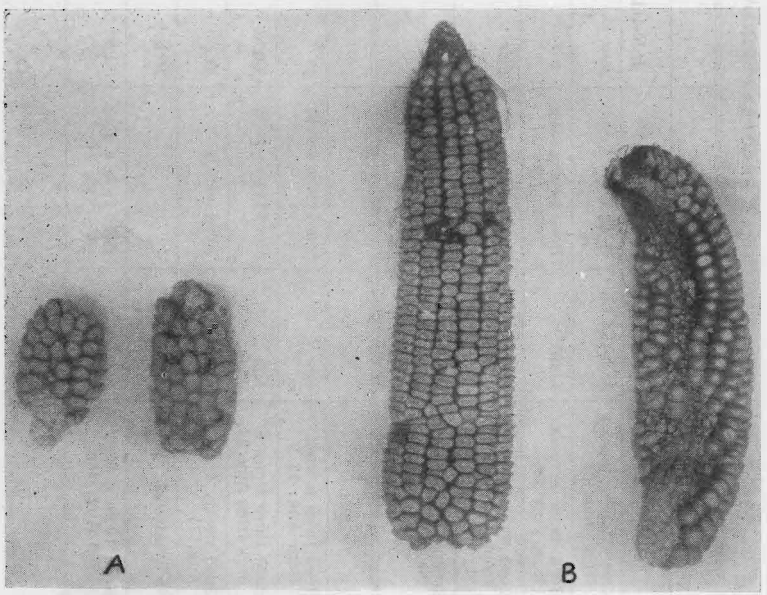

Fig. 9. The European bindweed reduces the yield of corn. A. Corn from one hill where the bindweed infestation was heavy. B. Corn from one hill in plot kept clean by hoeing.

TABLE 16. INFESTATION BY EUROPEAN BINDWEED FOLLOWING FREQUENT CULTIVATIONS.

Plot no.	1930	1931		1932		1933	Remarks
	Treatment	Infestation	Treatment	Infestation	Treatment	Infestation	
1	Kept clean by hoeing from June 26	Light	Hoed (10)	Few	Alsike clover, hoed (2)	0	Alfalfa good, 1934. No bindweed.
75	Hoed twice a week from July 28	Light	Hoed twice a week from June 16	0	Hoed twice a week July 2 to Sept. 17	0	Alfalfa good, 1934. No bindweed.
76	Hoed twice a week from July 19	Light	Hoed (13)	Few	Hoed (6) to Aug. 1, twice a week to Sept. 17	0	Alfalfa good, 1934. No bindweed.
80	Ground kept clean by hoeing from July 21	Heavy	Spaded Hoed (14)	Light	Hoed (6) to Aug. 11, twice a week to Sept. 19	0	Barley, alfalfa seeded in 1933. Good.
	1931	1932		1933		1934	
199	Hoed twice a week from Aug. 15	Few	Hoed twice a week	40	Hoed weekly	18	Fallowed, alfalfa. No bindweed, 1935.
200	Hoed three times a week from Aug. 13	Few	Hoed twice a week	Light	Hoed weekly	14	Fallowed, alfalfa. No bindweed, 1935.
201	Hoed weekly from Aug. 15	Light	Hoed weekly	Light	Cultivated (3)	Light	Fallowed, alfalfa, 4 bindweeds, 1935.
202	No treatment	Light		Heavy	Cultivated (3)	Light	Fallowed, alfalfa, 8 bindweeds, 1935.
210	Hoed twice a week from Aug. 14.	Light	Hoed twice a week to Sept. 17	Light	Alfalfa	Light	Alfalfa, 1934. 4 bindweeds, 1935.

Four plots (1, 75, 76, 80) hoed twice a week or more frequently (plot 1) in 1930 and hoed again in 1931, had to be hoed the third year in order to exterminate all the bindweeds. The bindweeds in plot 1, however, were cut off only twice during the third season. Hoeing or cultivation begun in June was more effective than that postponed until July or August (199, 200). The bindweeds remaining in the fourth year, where cultivations were begun in August, 1931, were eliminated by fallowing and seeding to alfalfa. Plot 201 which was given weekly hoeings beginning Aug. 15, 1931, was covered with bindweed in 1933. Although the data are not sufficient to draw definite conclusions for general recommendations, there are indications that the removal of the aerial parts once a week is not sufficient and that cultivations three times a week do not appear to be any better than semi-weekly cultivations.

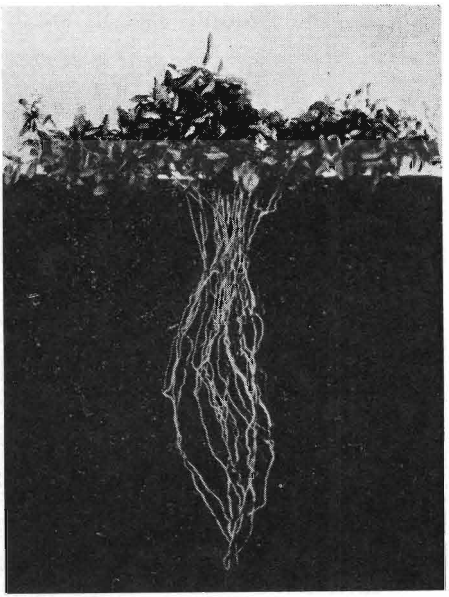

Fig. 10. Regeneration takes place at varying depths, often reaching 2 feet or more. Frequent cultivations are effective in destroying the numerous rhizomes which are formed.

Experiments to determine the effectiveness of fallowing fairly large areas of European bindweed were begun at Hawarden on June 1, 1933, on two fields, one about ½ acre in extent and the other 1½ acres. All the ground used was heavily infested with bindweed. Cultivations were made twice a week with the aid of a spring tooth harrow from June 1 until Oct. 1. There was a noticeable reduction in the number of plants the second year. "Scattered" plants were not as vigorous the second year. Cultivations continued throughout the second year for the same period and at the same rate, further decreased the number of plants, and before they were exterminated the rhizomes were almost thread-like in appearance. In 1935 there were no bind-

weeds in the ½-acre tract, but in the second field a patch of about 2 square rods was still alive. In making an excavation to determine the probable cause of this resistance to cultivation, it was found that the tap roots penetrated to a depth of 20 feet.

In 1931 a strip of ground 1 rod wide and 40 rods long was plowed through a corn field and cultivated semi-weekly with a spring tooth harrow until the latter part of September. The following year the ground was in small

Fig. 11. The European bindweed grows rapidly, often forming a dense mat of aerial growth. On shading, the bindweed twines (counter clockwise) about any nearby support.

grain. Fallowing was again resumed the middle of July and continued until October. The bindweeds were not sufficiently reduced in number to make this procedure of much importance.

Clean tillage may be expected to eradicate the bindweed, but the method entails much labor and considerable expense.

THE EFFECT OF FREQUENT CULTIVATIONS BEGUN IN JULY UPON SUBSEQUENT CROPS

Tests of frequent cultivations, begun July 15, upon the growth of bindweed and subsequent crops (corn, sweet clover) were begun in 1932. The data are given in table 17.

Bindweed plots established in corn, cultivated weekly (plots 287, 288) and semi-weekly (plots 289, 290) did not appear to have a reduced number of bindweeds. Upon cultivation in 1933 there were only "few" bindweeds. After fallowing in 1934, and seeding to sweet clover on June 21, the bindweed counts were the same as the previous year. Although there was a heavy growth of sweet clover in 1935, the infestation in 1936 ranged from "scattered" to "light."

The average yield of corn upon the intensively cultivated plots was 14.6 pounds in 1932 and 57 pounds in 1933. The control plot (273) yielded 17.4 pounds of corn in 1932 and the following year 35 pounds.

USE OF COMPETITIVE CROPS

Call and Getty (16) state that for large areas, competitive or smother crops are the most promising when the moisture supply is certain, and when the moisture supply is uncertain the smother crop to be practical must be grown after intensive fallowing. In Kansas cane is the best annual smother crop for bindweed.

Zahnley and Pickett (44) have recommended plowing the infested land soon after the bindweed appears in the spring and cultivating at intervals of 7 to 10 days. The same plan is followed the second year, until July, when cane is seeded.

The effect of fallowing from the middle of July, followed with cane and sudan grass, upon the reduction in the number of bindweed was tested in 1931.

The data are given in table 19.

Intensive cultivation from July 19, followed with intensive cultivation the early part of the following year and the seeding of cane and sudan grass, reduced the number of bindweeds to "light" in 1932. This treatment, along with three cultivations in 1933, apparently reduced the vigor of the bindweeds so that the two sprayings of sodium chlorate in 1932 eliminated all of the bindweeds. It is not possible to make direct comparison between sudan grass and cane with rye (plot 79), as the rye was seeded in the fall and given one spraying of sodium chlorate in 1931.

Immediately after the oats were cut in 1933, at Ha-

TABLE 17. INFESTATION BY BINDWEED FOLLOWING CULTIVATION FROM JULY 15, AND SUBSEQUENT CROPPING WITH CORN AND SWEET CLOVER.

Plot no.	1932	1933		1934		1935	Remarks
	Treatment	Infestation	Treatment	Infestation	Treatment	Infestation	
287	Hoed weekly from July 15	Heavy	Cultivated (3)	Few	Sweet clover seeded June 24	Scattered	Bindweed climbing stems of sweet clover.
288	Hoed weekly from July 15	Heavy	Cultivated (3)	Few	Sweet clover seeded June 24	Few	Few bindweeds, 1935
289	Corn, hoed twice a week from July 15	Heavy	Corn, Cultivated (3)	Few	Sweet clover seeded June 24	Few	Few bindweeds, 1935
290	Hoed twice a week from July 15	Heavy	Cultivated (3)	Few	Sweet clover seeded June 24	Few	Few bindweeds, 1935
273	Cultivated (3)	Heavy	Cultivated (3)	Heavy			

TABLE 18. INFESTATION BY BINDWEED FOLLOWING CULTIVATION FROM JULY 19 AND SUBSEQUENT CROPPING WITH CANE AND SUDAN GRASS.

Plot no.	1930	1931		1932		1933	Remarks
	Treatment	Infestation	Treatment	Infestation	Treatment	Infestation	
77	Ground kept black by hoeing from July 19	Heavy	Cane	Light	Hoed (3) $NaClO_3$(2)	0	No bindweed in 1934.
78	Ground kept black by hoeing from July 19	Heavy	Sudan grass	Light	Hoed (3) $NaClO_3$(2)	0	No bindweed in 1934.
79	Ground kept free of weeds from July 22, by hoeing, winter rye	Medium	$NaClO_3$	Few	Hoed (2) $NaClO_3$(2)	0	Alfalfa light in 1934.

warden, a piece of ground about 2 acres in area was plowed on July 18 and seeded to cane at the rate of 30 pounds per acre. The cane grew rapidly from the start and attained a height of more than 8 feet by the middle of September. At that time the cane was plowed under. In April, 1934, oats were seeded on this ground, but the crop was light. There were "scattered" bindweeds that fall. As soon as the grain was cut and the stubble plowed, it was again seeded to cane. But the cane, through lack of moisture, did not germinate for 2 weeks and by the time of killing frost had not attained a height of over 2 feet. Under this environment the bindweeds increased in number. The reduction in the bindweed population by the growing of small grain and cane the same year may be satisfactory, if there is sufficient moisture to insure rapid growth of the sorghum.

Millet and cane have been used as smother crops in the Hawarden experiments. Varieties which seemed to give the best results were the ones which grew actively throughout the season and matured late. A German millet, grown in Manchuria and imported into the United States, has given better results on bindweed-infested ground than our common millets. It is coarser and attains a greater height than the regular German millet. The "sumac" variety of cane also has proved to be better than the "black amber."

Good results have been obtained with the use of soybeans drilled at the rate of 2 bushels per acre. In 1934 soybeans were seeded on an area of about ½ acre. The ground was plowed in the spring and fallowed until the first part of June. As soon as the soybean hay crop was harvested, the ground was plowed. The same cropping procedure was followed the next year. As a result of 2 years of soybeans, the bindweed population was reduced approximately 70 percent.

In 1934 about 10 acres of soybeans were planted in rows 19 inches apart, and cultivated with a beet cultivator. The infestation of bindweed was not reduced by this method of growing soybeans.

If smother crops are to be effective in reducing the infestation of bindweed, it is necessary to have sufficient soil moisture to insure prompt germination of the seed. It is also necessary to have a heavy stand of the smother crop, along with active growth throughout the season.

ALFALFA

Cox (17) states that bindweed can be smothered out by alfalfa. Barnum (10) also stated that a good stand of alfalfa will kill the bindweed. Call and Getty (16), working in Kansas, found that alfalfa, under favorable conditions, seeded from the middle to the last of August, made a good growth by the time of the first hard freeze, but the bindweed roots and rhizomes were killed at a short distance below the soil surface. The plan to be successful depends on: 1. Having land that will grow alfalfa; 2. the weakening of the bindweed by a season of thorough cultivation; 3. the acquisition of a good stand of alfalfa. Even with these definite statements in regard to the effectiveness of alfalfa, there has been little experimental work done, however.

Alfalfa is extensively grown in many areas where heavy infestations are present. It was thought that if the ground was spaded to a depth of 10 to 12 inches and shortly seeded to alfalfa in August, an effective means of reducing the number of bindweed might be found. Deep plowing cuts off the bindweed roots and thus necessitates a long time for the production of green tissue. Since the bindweed is usually killed back to the ground during the winter, the shoots appearing after the alfalfa was seeded would be killed. The bindweed is late in appearing in the spring, and the alfalfa should therefore get a good foothold before the bindweed appears. The data where deep cultivation and fall seeding of alfalfa have been tried are given in table 19.

Plots 196 and 198, spaded, cultivated and seeded to alfalfa in August, 1931, had "few" bindweeds in 1934. Plots 206 and 208, fertilized shortly before seeding to alfalfa, did not show any greater reduction in the number of bindweed. The stand was much better, however.

Sweet clover followed by rye (plot 205) one season did not show any reduction in the bindweed population in 1933. Rye seeded upon deeply tilled ground (plot 197) allowed only "light" infestation the next year. This particular plot was given one spray application of sodium chlorate in 1932 and then seeded to alfalfa in 1933, and all the bindweeds were exterminated.

A combination of tillage, cropping and spraying in the eradication program may be possible. The spring seeded alfalfa (plot 207) was not nearly as effective as the seeding made the latter part of August. There is a distinct advantage in employing deep tillage and combining this

TABLE 19. INFESTATION BY BINDWEED SUBSEQUENT TO DEEP TILLAGE, FOLLOWED WITH ALFALFA.

Plot no.	1931	1932		1933		1934	Remarks
	Treatment	Infestation	Treatment	Infestation	Treatment	Infestation	
196	Spaded Aug. 13, cultivated, alfalfa seeded Aug. 29	Light		Few		Few	
197	Spaded Aug. 13, cultivated, rye seeded Aug. 29	Light	$NaClO_3$	15 seedlings	Hoed Alfalfa	0	
198	Spaded Aug. 13, cultivated, alfalfa seeded Aug. 29	Few		Few		Few	
205	Spaded Aug. 13, barnyard manure added	Few	Sweet clover Winter rye	Light	Hoed Cultivated (2)	Light	Fallowed, seeded to alfalfa, 1934. No bindweed, 1935.
206	Spaded, "Vigoro" fertilizer, alfalfa	Few		Light		Light	
207	Spaded, "Vigoro" fertilizer	Medium	Alfalfa (spring)	Medium		Medium	
208	Spaded, barnyard manure, alfalfa	Few		Few		Few	
209	No treatment	Medium		Heavy	Barley, barnyard manure	Heavy	

with a fall seeded crop, such as alfalfa, in reducing the number of European bindweed.

In 1931 about 8 acres of ground heavily infested with European bindweed, which had been in winter rye, were plowed early in August and cultivated until Aug. 31; then they were seeded to Grimm alfalfa at the rate of 20 pounds per acre. After the seeding the ground was rolled so as to form a firm seed bed. In the fall of 1931, because of timely rains in September, the alfalfa became firmly rooted before the killing frost. Frequent observations were made from that time on to ascertain whether any bindweed was present. A strip of this ground was plowed Aug. 1, 1935, and at the time of killing frost no bindweeds were found. Two acres of ground prepared in the same way but seeded to sweet clover in the spring of 1932 did not show any material retardation in the bindweed population. Success of alfalfa following rye is probably due to the fact that the upper portions of the bindweed roots are cut off in the preparation of the seedbed, giving the alfalfa a chance to become rooted. In the spring the alfalfa is ready to resume growth as soon as the temperature permits, but bindweed starts growth later.

Alfalfa has proven able to compete with the European bindweed, as in all cases it has reduced the bindweed population. Addition of barnyard manure or of a complete fertilizer has brought forth better results with the alfalfa than where no fertilizer was added. Sweet clover has not been as effective as alfalfa. Winter rye can give material assistance in the eradication program. This is possibly explained by the fact that the rye is seeded in the fall when the bindweed does not grow as actively as it does earlier. In the spring the rye begins its growth much earlier than the bindweed.

ALFALFA TOLERANT TO SODIUM CHLORATE

Where alfalfa will grow, it is found that this plant fits into the program of bindweed eradication, whether one uses fallowing, competitive crops or sodium chlorate. It has been found that alfalfa is one of the most tolerant of common agricultural plants to sodium chlorate. Sweet clover is also practically in the same scale with alfalfa. This is not a characteristic of the *Leguminosae* in general, as it has been found that soybeans are extremely sensitive. Corn, sorghum and millet may be grown satisfactorily on ground where weeds have been killed through the use of sodium chlorate, when soybeans, on the other hand, become brown, wither and die. Soybeans have shown char-

acteristic chlorate browning and stunted growth the third year after the final sodium chlorate treatment. Oats and barley are sensitive to traces of sodium chlorate in the soil and should not be planted until the second year after the last application of chlorate.

GRAZING

The possibility of using sheep and hogs in exterminating the European bindweed was tried during 1931-33.

USE OF SHEEP

In a ½-acre enclosure, heavily infested with bindweed, six western lambs totaling 470 pounds were placed on July 18, 1931. On July 25, six lambs weighing 500 pounds were added. On Aug. 19 all the European bindweed was grazed to the ground. It became necessary to feed the sheep small grain as well as green fodder. On Aug. 19 one of the lambs died. On Sept. 14 the five lambs of the first set weighed 450 pounds. The bindweed infestation the next year did not show any reduction.

In 1932, 18 sheep were placed in the same ½-acre pasture on June 21. At that time there was a heavy infestation of the European bindweed. On July 13 the sheep were removed as no green growth was present. They were returned Aug. 1. It was necessary to do this off and on throughout the season. In 1933, sheep were again placed in the enclosure, and the results were about the same as those experienced in 1932. In 1934, upon examination of the bindweeds, it was found that there was still a heavy infestation. The experiment with sheep was not continued.

USE OF HOGS

Stewart and Pittman (42) claimed that they could reduce the bindweed population 75 percent by pasturing an infested area with hogs. Barnum (10) stated that hogs in certain instances will kill the European bindweed.

On July 18, 1931, 19 yearling sows were placed in an ½-acre enclosure heavily infested with European bindweed. Corn in the enclosure, with some of the bindweed, was trampled under foot. There was very little rooting by the hogs. In 1932 ground was plowed and hogs were again placed in this pasture. To encourage rooting by the hogs, slacked coal and salt were placed in a number of holes dug with a post-hole auger. On the following year there was a heavy infestation of bindweed. Hogs were again pastured in the enclosure in 1933, but the results

TABLE 20. INFESTATION BY BINDWEED FOLLOWING COVERING WITH TAR PAPER.

Plot no.	1930	1931		1932		1933	Remarks
	Treatment	Infestation	Treatment	Infestation	Treatment	Infestation	
81	Covered with tar paper	Heavy	Re-covered with tar paper		Re-covered with tar paper $NaClO_3$	0	Alfalfa seeded in 1933. Good.
	1931	1932		1933		1934	
213	Covered with tar paper		Re-covered $NaClO_3$	7	Alfalfa	14	3 bindweeds, 1935.

were not any better than in the previous years, so the experiment was terminated.

From the results of these experiments it is clear that sheep and hogs cannot be considered as effective agents in the eradication of the European bindweed.

THE EFFECT OF LIGHT EXCLUSION

Light is one of the essentials necessary for the growth of autotrophic plants. If light is excluded long enough the plants will die. Covering bindweed areas with tar paper should then in time eradicate the plants. Two plots (81, 213) were covered with heavy "mule-hide" tar paper. The data are given in table 20.

A covering of black paper is effective in European bindweed control but the cost is high. According to the results given in the table, it would take 3 years to make a complete extermination. As the paper breaks, and develops cracks through which the shoots penetrate, it becomes necessary to re-cover each year. At times when a new covering is made, it may be advantageous to spray the protruding shoots with sodium chlorate. The amount naturally will be small.

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